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FATIGUE OF METAL IN WROUGHT IRON AND STEEL FORGINGS.

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My connection with one of the large forges of the country has brought me for several years in contact with persons who use forgings of both iron and steel in their respective lines of business, and in conversation with them I have frequently been surprised at the misconception that many of them have regarding the comparative properties of these metals and especially their ability to resist repeated stresses.

They tell me, for instance, that they prefer wrought iron to steel for the connecting-rods and crank-pins of their engines, because steel, having no fiber, is brittle and snaps suddenly, while wrought iron, being fibrous, does not. They say that

both iron and steel crystallize from shock, but that wrought iron, being tougher, will outlast steel in such service as is performed by piston-rods of steam-hammers. They say that low carbon steel is softer than high carbon steel, and is, therefore, less brittle and not so apt to break in the forged parts of their machines.

Most of these persons know better, but have not given the subject sufficient thought, or they would perceive that their statements are not consistent.

They know that steel cannot at the same time be stronger than iron, and yet be more brittle.

There is not one of them who would advocate the use of the old "cut nail," which was made of iron in place of the "wire nail," which is made of steel. They all know, if they only call it to their minds, that all metals are crystalline, iron and steel among them, and those who have looked into the matter carefully, know that the fiber in wrought iron is due entirely to the slag which has been incorporated in it in the process of manufacture. Many of us have seen the laboratory experiment of passing chlorine gas through a glass tube containing a piece of wrought iron. We remember how the iron was dissolved out, leaving a skeleton of slag of the same shape as the piece of iron. Here and there in the interior of the skeleton could be seen accretions of slag which, imbedded in the original piece of iron, would have weakened it appreciably. Instead, therefore, of being an element of strength in wrought iron, the fiber, which is looked upon as adding strength, is evidence of an impurity which is a source of weakness. And yet this fibrous appearance is not a necessary characteristic of good wrought iron. Any blacksmith will break a bar of iron in such a manner as to cause either a fibrous or a crystalline fracture. Then, again, wrought iron may be so poorly manipulated in the puddling process that, if worked at too high a heat, a portion can become actually melted into steel, or, if at too low a heat, some of the cast iron from which it was made may remain in its original condition. In either case a crystalline structure would be shown in a fracture.

It was to the metallurgist almost alone, who knew the advantages of using a metal which has been initially in a fluid condition, and from which, while in this state, all slag and similar impurities have been eliminated, that we owe the present development of the steel industry.

The superior strength of steel and its more perfect homogeneity have driven iron rails and iron structural material completely from the market. It is, however, curious to note that although this change took place from twelve to fifteen years ago, it is only recently that steel has to any great extent superseded wrought iron for forgings, and, as I have already stated, there are at the present day many users of wrought iron forgings who seem to be unwilling to make the change.

*Fig. 1** shows a series of drop tests made on pairs of bars of wrought iron and steel of the same size to compare their relative strength. These tests are reported by Prof. L. V. Tetmayer, in the records of the Test Bureau at Zurich, Switzerland. All the bars were furnished by the well-known works of Wendell & Co., Hayauge, Loraine. The chemical composition of the two metals was as follows:

	C.	Si.	P.	S.	Mn.
Wrought Iron	·05 to ·06	·05 to ·15	·30 to ·50	·02 to ·04	trace
Steel	·08 to ·12	trace	·03 to ·06	·02 to ·04	·40 to ·70

[The high percentage of phosphorus in the wrought iron was due to the slag.]

The weight of the drop was 661 pounds. The height of fall and number of strokes was as follows:

	1⅝″ square		2⅛″ square		2½″ square		3¼″ square		4″ square	
	W. I.	Steel	W. I.	Steel	W. I.	Steel	W. I.	Steel	W. I.	Steel
Fall	8·66″	8·66″	18·9″	18·9″	28·35″	28·35″	50·4″	50·4″	78·74″	78·74″
Strokes	2	3	2	3	1	4	1	7	1	6

It will be noted that in each instance the steel bar received more severe treatment than the wrought-iron bar, but with

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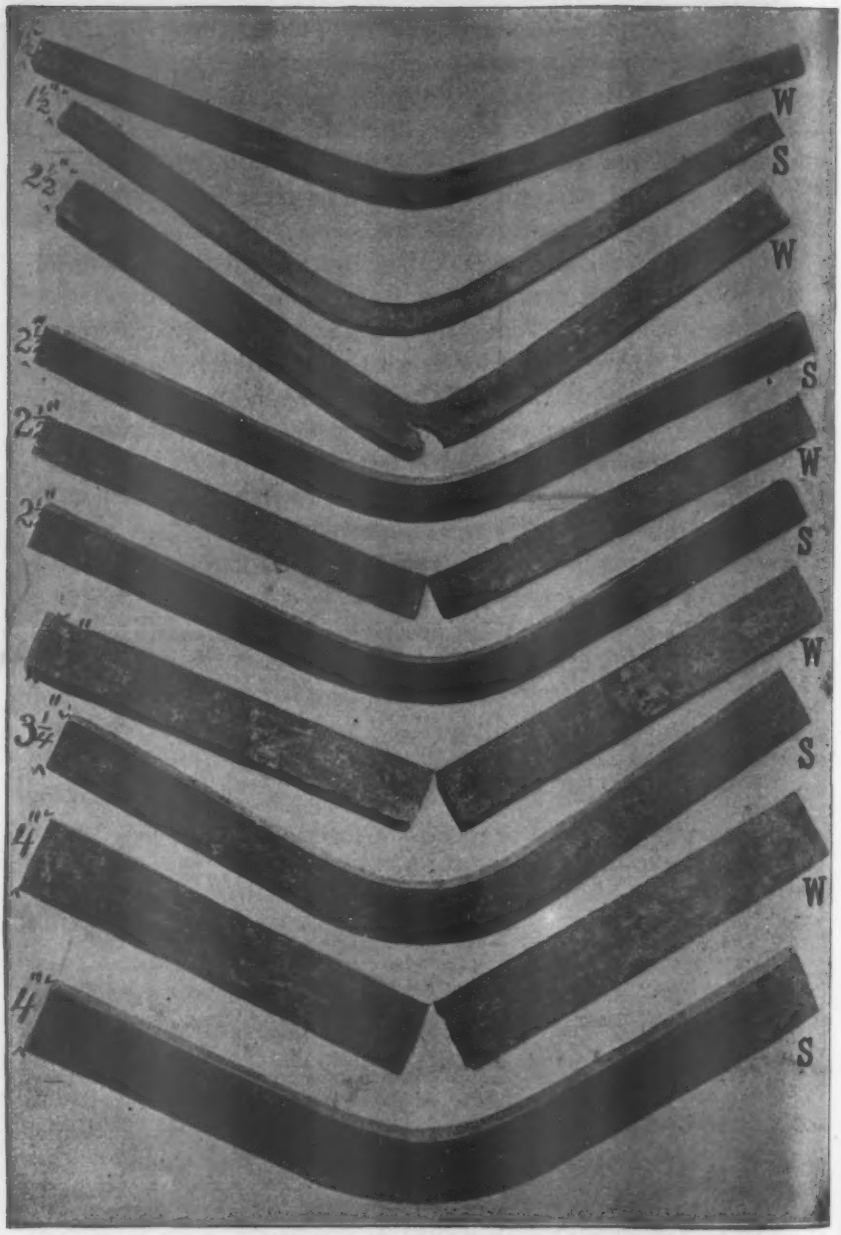


FIG. 1.—Comparative drop tests of wrought iron and steel.

far less damaging results. Do these tests show that steel is more brittle than wrought iron?

Let us look into the reasons for the primal reluctance of the trades to adopt steel for forgings, and see if they are still cogent and a preference for wrought-iron forgings now legitimate.

Going back to the time when the large rolling mills of the country changed their product from iron to steel, we find that the industrial conditions of the country were not such as to demand forgings of any considerable size. The forges then in existence were equipped with small hammers, which, by taking advantage of the property of welding possessed by wrought iron, were of sufficient capacity to build up such small forgings of that metal as were demanded.

As soon, however, as manufacturers knew that there was a new material in the market that was stronger and more reliable than wrought iron, they appreciated that, by its adoption for forgings, they could reduce the size of many parts of their machinery, and at once made a demand upon the forges for forgings made of it.

Had the forges made modifications in their equipment to the same extent that the rolling mills had, in order to meet the requirements of the new material, without doubt satisfactory steel forgings could have been produced. No such changes, however, were made, and such steel forgings as were produced were made under an inadequate understanding of the processes necessary for turning them out.

Steel does not possess to the same degree as wrought iron the property of welding. Instead, therefore, of building up a forging of small pieces, it is necessary to work down the finished piece from a block of steel of considerable size. It should be, in fact, twice its size, in order that the proper amount of work necessary to make it a forging should enter into the metal during its reduction in size by the forging process. For instance, a 12-inch shaft, made of iron, would be built up of small pieces, 4 or 5 inches thick, welded together. For a steel shaft of the same size, on the contrary, best practice would require forging down a piece of steel 24 inches in

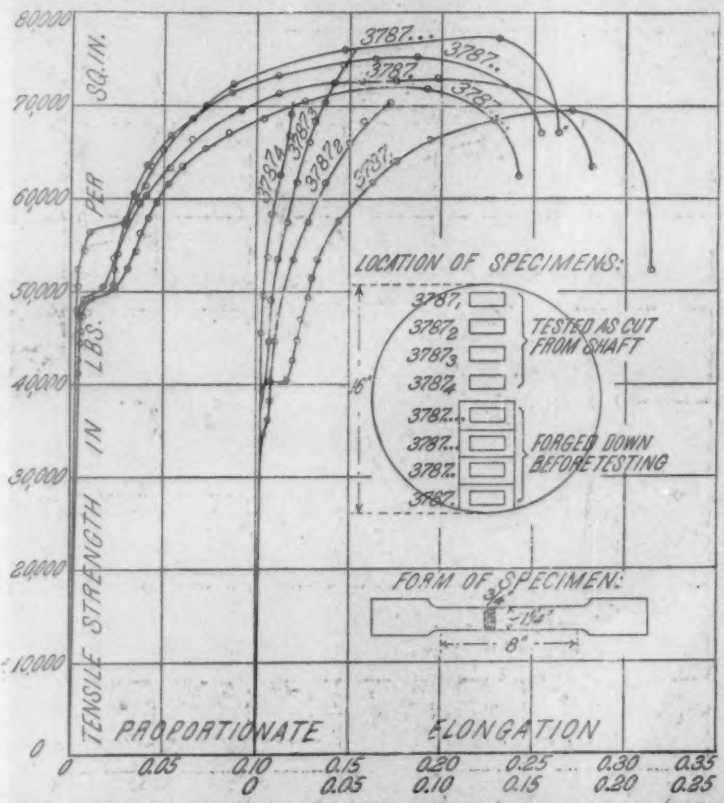
diameter under a hammer whose blow could be felt through 24 inches of metal instead of only 4 or 5 inches.

When, therefore, the manufacturers of the country called for steel forgings, in the first place the forges did not have the hammer equipment necessary to make them, and there were other ample reasons for their not being able to supply them, as will be appreciated when we view the processes which are now considered necessary for turning out good work. Many forges did not hesitate, however, to supply as good steel forgings as they could make with their incomplete equipment, and having so begun, they have continued ever since to supply work of the same character, which has not been, and cannot be, satisfactory, as I think will be made clear as we go further into the subject. The result is that an undefined prejudice has unjustly been established in the trades against steel and in favor of wrought-iron forgings, and it has been kept fresh in the minds of the uninformed up to the present time to a great extent through these forges themselves, who seem to have been unwilling to equip themselves properly for turning out steel forgings.

The diagram, *Fig. 2*, shows a series of tests of the metal of a shaft made at the time of which we are speaking, and shows its condition as the result of attempting to make a large forging under a light hammer.

This shaft, a section of which is shown by the circle, was 16 inches in diameter, and was made for the United States Dispatch Boat *Dolphin*, under a 10-ton hammer from a 30-inch steel ingot, and after it had been in service but a very short time it broke. The broken section was sent to the Government Testing Bureau, at Watertown, to determine, if possible, the cause of failure. Test pieces of the size and shape indicated in the lower part of the diagram were cut out of the upper half of the shaft at varying distances from the center, as shown in the sectional drawing, and were marked respectively 3,787, with subscripts 1, 2, 3 and 4. The results of the tests are shown by the curves bearing their respective markings, and the records can be read in the lower line of figures underneath the diagram. The outer specimen gave an elongation

of 21·4 per cent., the second one of 5·5 per cent., the third one of 4·9 per cent. and the one nearest the center of but 2·0 per cent. In other words, the ductility or toughness of the metal varied from 21·4 per cent. to 2 per cent. between the surface and the center, showing that the former metal only had been



* FIG. 2.—Graphic representation of effect of forging 16″ steel shaft of U. S. Cruiser *Dolphin* under a hammer of 10 tons falling weight.

worked under the light hammer, while the latter remained in the condition of the original steel ingot. In order to further prove that the failure of the shaft was due to the metal not having been worked sufficiently, and that if it had been worked more thoroughly it would have been tougher, specimens of

* By permission of Prof. J. B. Johnson.

Fig. 3.—Broken 12″ steel shaft forged under hammer of 10 tons falling weight. Crystalline center of original ingot not affected by blows of light hammer.

larger size were taken from the lower half of the shaft, as shown, and marked 3,787. — 3,787.. — 3,787... — 3,787.... and these were forged down until they were of the same size as the specimens taken from the upper half. In other words, work was put into the metal of the test bars by forging them down which ought to have been put into the metal of the shaft during the original forging process. The records of these tests can be read in the upper line of figures underneath the diagram. The four bars showed an elongation of 25·4, 28·2, 26·4 and 24·1 per cent. respectively, or an average of 26 per cent., which showed conclusively that the cause of the break was due not to any inherent weakness in the metal, but solely to lack of work in the center metal.

Prof. R. H. Thurston, at a meeting of the American Society of Mechanical Engineers, held in 1886, in this very room, made the following remarks regarding this shaft: "I examined the steel shaft of the *Dolphin*, the United States steamer recently made famous by the unfortunate misunderstanding between Mr. Roach and the Navy Department, which has led us to so strongly sympathize with that enterprising builder of late. I found the section fractured, exhibiting most excellent structure near the surface; but it was very strongly crystalline, apparently, near the center. It had, I judge, been too heavy a job for the hammer available for forging it; the crystals had been produced while heating it, and had not been broken up in forging, in consequence of the fact, I have no doubt, that the effect of the blows could not reach the core. The tenacity of the outer part of the shaft was evidently fully up to the standard; but the center had lost its strength very greatly."

Fig. 3 shows a 15-inch steel shaft also made about this same time under a hammer of 10-ton falling weight, which was about the heaviest in use in those days and even at the present time is the weight of those used at most forges to turn out their heaviest work. The center shows the crystalline condition of the original ingot, and it is evident that the effect of the hammer was not felt very far below the surface.

Fig. 3.—Broken 12" steel shaft forged under hammer of 10 tons falling weight. Crystalline center of original ingot not affected by blows of light hammer.

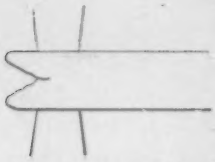


FIG. 4. — Effect of forging under a light hammer.

The effect of the hammer may also be to draw out the surface metal and leave the center behind to such an extent as to cause cracks and even cavities in the latter, which are apt to develop in service and cause rupture. *Fig. 4* shows the appearance of the end of almost all hammered shafts. The drawing out of the surface metal at the end is indicative of what has occurred throughout their length.

Fig. 5 shows a broken 15-inch steel shaft forged under a 10-ton hammer, which shows very plainly the tearing effect referred to.

The above are some of the defects in steel forgings which have caused their failure in the past and which have tended to prevent their coming into more general use. They are all due to faulty methods of manufacture.

Notwithstanding the prejudice which these defects have occasioned in favor of wrought-iron forgings, manufacturers are beginning to find that the latter are becoming less and less reliable. One reason for this is that the industrial condition of the country has changed so as to demand larger forgings. Another reason is that as the change from iron to steel is becoming more and more complete throughout the country, the supply of wrought-iron scrap is getting gradually less and steel scrap more plentiful, and as there is no way of distinguishing these metals apart in rapid handling, it is with difficulty that pieces of steel scrap can be prevented from becoming incorporated in wrought-iron forgings. Whenever this occurs, the two metals do not weld satisfactorily, and points of weakness are occasioned which eventually lead to fracture. *Fig. 6* shows a wrought-iron shaft broken from this cause. The piece of steel can be seen projecting from the section of shaft in the foreground.

Many failures of forgings in the past, which were the direct results of improper manipulation in manufacture, have been attributed by the uninformed to the "crystallizing effect of shock" or to "fatigue of metal from alternating stresses" in service, particularly when the failures occurred to such forg-

metal torn by surface impact of light hammer.

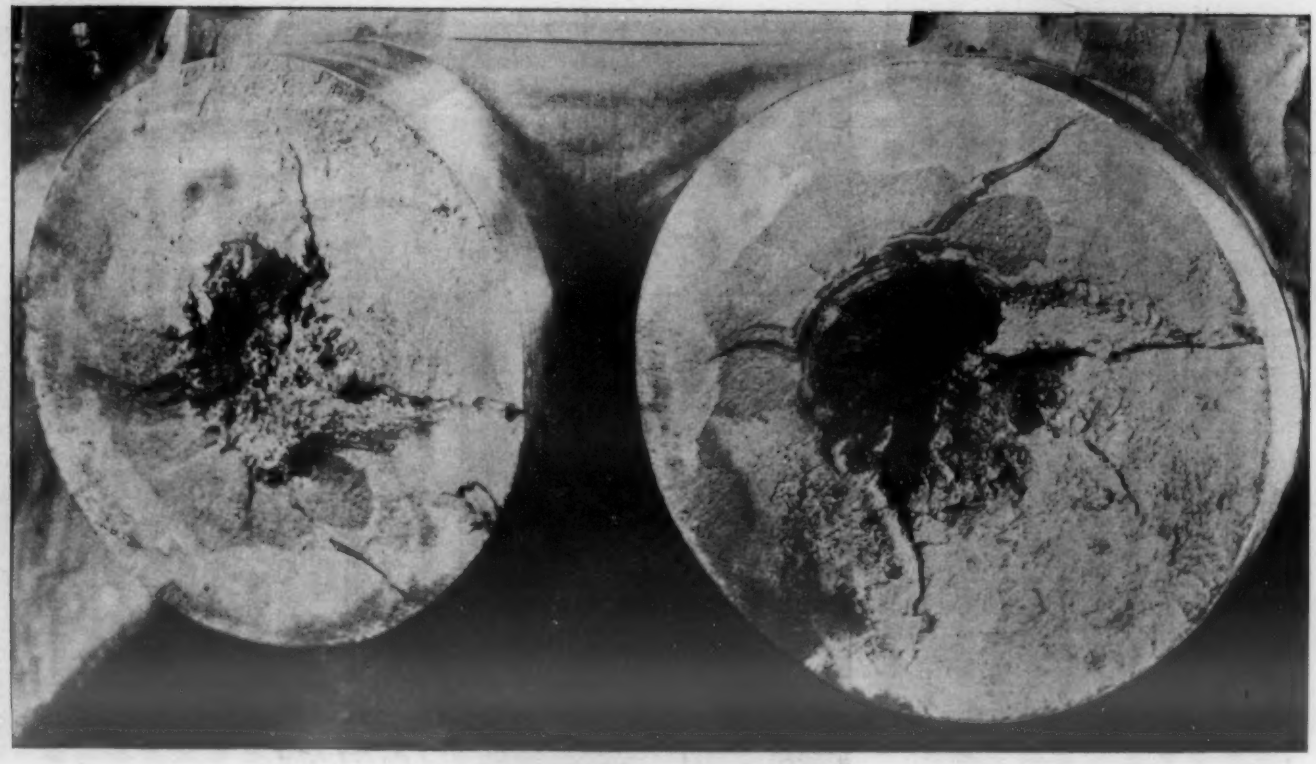


FIG. 5.—Broken 15″ steel shaft forged under hammer of 10 tons falling weight. Piped center of original ingot enlarged and metal torn by surface impact of light hammer.

ings as steam-hammer rods or to connecting- and piston-rods and crank-pins.

Since this time, however, we have learned more about both iron and steel than was then known, and although our knowledge of the subject of "fatigue of metal" from the effect of alternating stresses is still limited, we do know that these metals, being initially crystalline, do not become so from shock or other similar service when cold. We have also so far advanced in our methods of manufacture that we are now able to make forgings entirely free from the defects above noted, and which, if properly designed, will, when subjected to service of the character mentioned, last a very long time.

FIG. 6.—Broken wrought-iron shaft of Lake Steamer, showing piece of steel scrap in center.

What is this "fatigue of metal" of which we have heard and still hear so much? What is this mysterious cause to which so many failures in the past have been indiscriminately charged? Let us see what investigations into the subject have been made and what has been learned from them.

We find that, as far back as 1871, experiments were reported by Wöhler, in Germany, followed by Spangenberg and Martens and Bauschinger. In England the subject was similarly reported upon in 1886 by Mr., now Sir Benj. Baker, in his records of tests of material for the Forth Bridge, and it has

since been pursued systematically in this country by Mr. Jas. E. Howard, at the Government Testing Bureau, at Watertown. And after all the time and labor that has been devoted to the subject, what information has been derived? Simply that iron and steel are more amenable to the laws of the universe than we had previously given them credit for. That the same laws under which "continuous droppings will wear away a stone" are applicable to these metals. That frequent repetitions of load in amount far below the ultimate strength of the material will eventually break down its resistance and cause failure.

Beyond the bare statement of the above fact, laws of a general character have been formulated, but the complex nature of the situation prohibits exactness.

If we apply the same conditions to animate things, the results do not seem out of the ordinary. A good horse can, under favorable conditions, pull a load of several tons weight up a steep hill without serious discomfort. Compel him, however, to pull even one-tenth of the load up the same hill many times each day, week after week, and it would be only a question of a few months before his strength would give way.

No two pieces of metal are alike in chemical composition, and, if they closely aproach similarity in this respect, the difference in mechanical treatment during their manufacture causes them to possess widely different physical properties.

Generally speaking, however, we now know that for any given stress a certain number of repetitions produce failure, the greater the intensity of stress, the smaller the number of repetitions. We know also that the stress required to cause failure is less, and roughly speaking only half as great when the metal is strained alternately in opposite directions, as where it is strained in one direction only.

Let us, for instance, submit a bar of steel or iron to 30,000 pounds per square inch tensile, or to 30,000 pounds per square inch compressive stress. In either case the "range" is the same, viz.: 30,000 pounds. Now let us subject the bar to 15,000 pounds per square inch tensile and to 15,000 pounds

per square inch compressive stresses alternately, and, although the range is 30,000 pounds as before, the life of the material thus strained will be only half as long, although neither the tensile nor compressive stress approaches the elastic limit of the metal as closely as in the first two cases.

It is in fact very striking how regularly progressive the increase in the number of repetitions is as the range of stress decreases. In other words, the less the metal is maltreated, the longer it will endure, and, if we can make the range of stress small enough, a practically unlimited number of repetitions is required to cause failure. In "endurance tests" of this character, Wöhler found that the rupture of a bar of wrought iron by *tension* was caused by any of the following ways:

by	1	application	of	55,000	lbs.	per sq. in.
"	800	applications	"	51,500	"	" "
"	107,000	"	"	47,000	"	" "
"	341,000	"	"	42,500	"	" "
"	481,000	"	"	38,000	"	" "

a piece of spring steel, subjected to *bending*, broke as follows:

under	81,000	applications	of	95,000	lbs.	per sq. in.
"	154,000	"	"	85,000	"	" "
"	210,000	"	"	75,000	"	" "
"	472,000	"	"	65,000	"	" "
"	539,000	"	"	58,000	"	" "
"	1,165,000	"	"	53,000	"	" "

The apparatus used to make tests of this character is shown in its simplest form in *Fig. 7*. It consists of an ordinary lathe bed specially fitted at the driving spindle *n*, with a ball and socket chuck *j*. A babbitted box *k*, mounted on trunnions, is fitted to the other end of the bed. One end of the bar to be tested is screwed into the ball *i*, which is pressed against the face of the chuck by a helical spring *o;* the other end rests in the box *k*. A loose bronze flanged ring *b*, ½ inch wide, fits on the bar at its middle. A weighted lever, *d*, rests on this ring through the friction wheels *c*. The ratio of the arms of the lever is as 3 to 1. The fiber stress on

the bar can be regulated by varying the weight suspended at the end of the lever. By rotating the weighted bar through the driving spindle of the lathe, every fiber is subjected to bending alternately in opposite directions.

Thus conditions are imposed on the metal imitating those which occur in actual practice in such machine parts as railway axles, engine shafts, crank- and crosshead-pins, etc., where the fibers of the metal are subjected to stresses, continually varying from tension to compression.

The testing of metals to determine whether they possess specified physical properties is customary in order that a grade or quality may be obtained to meet the requirements of the service for which they are intended. For this purpose, certain simple and rapid standard tests have been determined upon in practice, to obtain respectively the maximum tensile, compressive and transverse strength of materials. It has been found from these that within a certain limit, which is approximately one-half of the ultimate strength, the metal is elastic, and if strained beyond this point its working strength

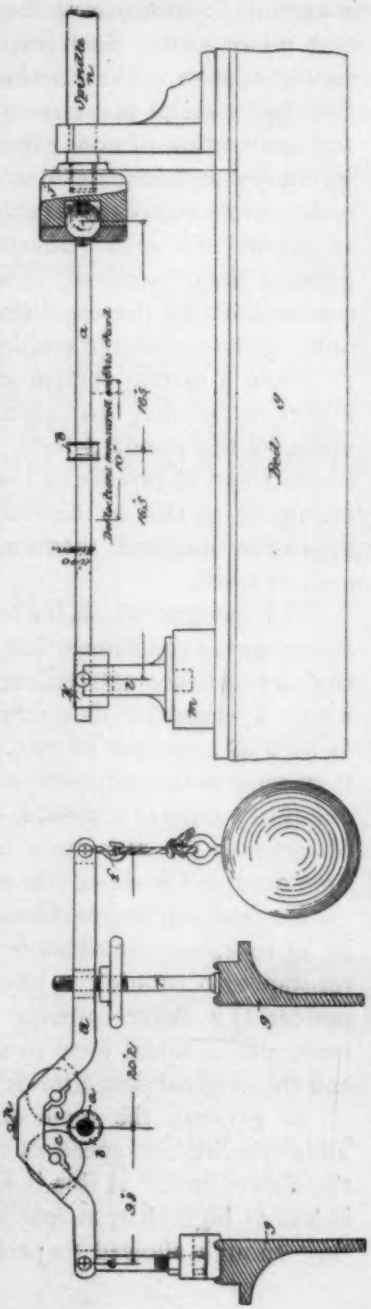


FIG. 7.—Apparatus for endurance tests of rotary shafts used at Watertown Arsenal.

is exceeded and it can no longer be depended upon to sustain even minor loads. Such tests give results, however, which are simply relative. Their actual significance is uncertain. The fact that a metal possesses a certain elastic limit, elongation and contraction of area when ruptured by once loading, fails to convey an adequate idea of what the same metal will do under circumstances of repeated stresses or when these stresses are applied in alternate directions, as they are in practice. Endurance tests, therefore, have been made with great care in connection with the usual standard tests above mentioned, in order to determine the relations that exist between the two.

From a careful comparison of these relations, knowledge is obtained so that through a determination of the qualities of metal by the standard tests, a prediction can be made of the conduct and endurance of the same metal in an actual service, analogous to that in the endurance test, which is a long and expensive one, and, therefore, impracticable for use in commercial work.

The speed at which the testing machine is operated varies according to conditions, but generally bars of very high tensile strength are rotated rapidly, in order to obtain results within a reasonable time. Sometimes the speed of rotation is as high as 2,200 per minute. At this speed stresses alternate from tension to compression at an interval of a little less than one-thirty-sixth of a second, or in passing from a neutral state of stress to the maximum tensile or compressive stress, the time occupied is about one-seventy-third of a second.

On starting the machine, if the bar is bent by the weight so as to cause considerable alternation of stress, a decided resistance to rotation is offered and the deflection decreases noticeably. After running for a short time, however, the molecules of metal seem to move more readily on each other and the original deflection is resumed.

In general, the molecular movements are not checked under the highest speed of rotation if the stresses are below the elastic limit. If this is exceeded, however, the deflection is less at high than at low speeds. Apparently, there is not time enough allowed to perform the work against molecular

friction and to complete the bending movement. In this case there is a rapid elevation of temperature. As this latter tends to prolong the life of the bar and as it is not obtained by any service in actual practice, the bar is rotated in cold water to keep the temperature as nearly constant as possible.

The following differences are noticed between steel bars run at temperatures of about 475° and 70°:

15	per cent.	carbon,	hot,	85,200	revolutions;	cold,	4,350	revolutions.
34	"	"	"	127,700	"	"	11,600	"
73	"	"	"	218,500	"	"	34,900	"

The following table gives the relative endurance of a series of bars of varying carbon, from the Bethlehem Iron Company, tested under a fiber stress of 40,000 pounds, which is below the elastic limit of all the specimens tested and is actually less than one-half of that of the strongest:

TABLE No. 1.

Specimen.	Tensile Strength.	Elastic Limit.	Extension in 2 inches.	Contraction.	Number of Rotations.
·24c. annealed	71,240 72,100	40,560 41,200	32·3 31·1	59·81 60·32	229,380
·24c hardened	74,440 73,930	45,170 44,150	33·13 31·00	69·93 70·19	348,000
·42c. annealed	80,855 86,410	44,290 47,040	23·00 26·6	56·7 51·63	225,900
·42c. hardened	92,180 89,990	55,000 53,170	26·05 26·8	57·22 59·88	655,600
·46c. annealed	94,600 98,180	48,060 48,060	21·15 21·6	47·65 39·83	976,600
·46c. hardened	102,880 104,400	61,110 62,130	23·05 22·5	51·27 50·42	1,657,500
·66c. annealed	124,200 127,720	65,205 65 920	7·15 11·95	17·28 20·54	3,689,000
·66c. hardened	154,920 153,380	92,040 92,040	13·5 13·05	31·48 30·15	4,323,600

The effect of the carbon content is conspicuous both in the standard and endurance tests.

Following are the results of tests on bars broken from time to time during the past few years at the Watertown Arsenal. The records of the wrought-iron bars are the average of a large number of tests:

TABLE No. 2.

Fiber Stress, lbs. per square inch.	40,000	35,000	30,000
	Rev's.	Rev's.	Rev's.
Wrought Iron	59,000	175,000	625,000
·16 per cent. C. Steel	193,000 170,000	763,000	
·17 " " "	162,000	970,000	
·34 " " "	317.000 236,000	14,100,000	
·55 " " "	160,000	3,600,000	
·73 " " "	454,000	15,290,000	12,548,000
·82 " " "	270,000 481,000	13,900,000	16,300,000
1·09 " " "		19,150,000	50,000,000 not ruptured.

These results, which are representative of many, show that the material, after a certain number of repetitions of stress, breaks with a fewer subsequent repetitions. It is impossible not to conclude, whatever the cause of decreased life of the bar may be, it is a cause which acts continuously, altering in some way its structure or properties.

A man of seventy years of age may be as sound as he was at twenty; but the fifty years have told on him nevertheless, and the breakdown is certainly near and may be sudden.

It would naturally appear likely that any gradually progressive alteration or fatigue of the bar would be manifested in some way in alteration of the ultimate strength, elastic limit or elongation of the bar, when tested in the ordinary way. This, however, does not appear to be the case. A bar subjected to so many repetitions of loading that it is known to be on the point of breaking, or a piece of bar already broken in an endurance test, gives in the ordinary testing machine no indications that its strength or ductility has been altered.

Specimens taken from the center of the bar, where the treatment has been most severe, show a higher tensile strength than those taken from the ends. This fact has led Mr. Howard, of the Watertown Arsenal, to suggest that possibly the effect of this treatment is similar to cold working the metal; that

ordinary, hot-worked metal is not left in its state of greatest tensile resistance, and that while repeated alternate stresses below the ordinarily accepted tensile strength eventually cause rupture, the metal in an intermediate stage passes through a state of increased resistance. He thinks we are not certain, when final rupture occurs, that the parts first to yield are not at the time in a state of maximum resistance, and the apparent loss in strength may be due to the accumulation of internal strains. Such speculations are extremely interesting and may lead to results that will be valuable. For the present purpose, however, we must confine ourselves to known facts. One of the principal of these is that the fracture of these bars is not crystalline. Usually, one-half of the specimen seems to have yielded first, and the metal there has the appearance of having worked upon itself, and has a dull leaden color, the other part has a fine granular structure. The left-hand side of *Fig. 8* shows a shaft which has broken from fatigue and has this characteristic fracture.

I might say that the concurrence of evidence from bars broken by fatigue, both in actual service and in the testing machine, is to the effect that there never has been a case found where it was known or could be demonstrated that any change in structure had taken place. And this goes to prove that materials of this kind are incapable of cold crystallization when exposed to the conditions of service mentioned.

Careful consideration of the results of endurance tests so far made leads to the recommendation of material for forgings which shall have a very high elastic limit and be so proportioned, if they are to be subjected to frequently alternating stresses, that these stresses shall at all times lie far within this limit.

In order to insure these two points, steel, not wrought iron, should be the metal used, and the higher the carbon content of the steel, the longer will be its life, other things being equal.

High carbon steel forgings, sound and free from internal strains, are by no means easy to produce. Much time and thought have been expended to devise methods for making

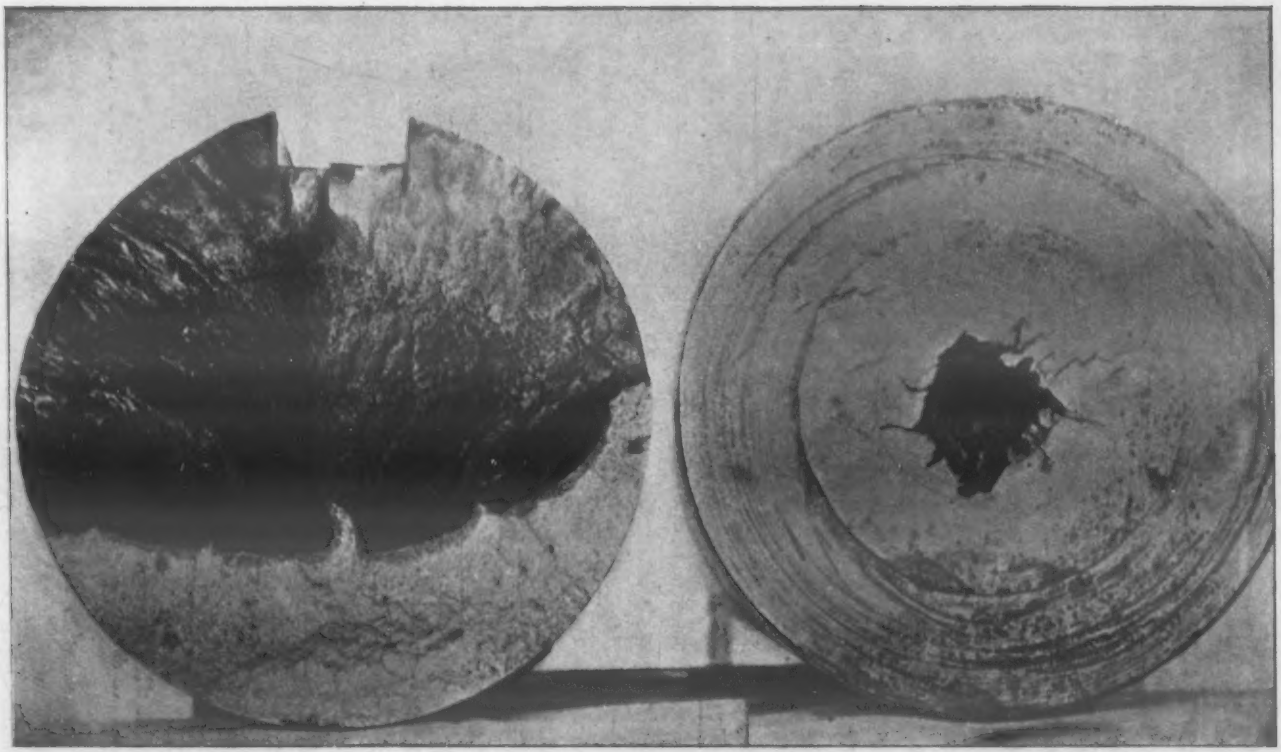


FIG. 8.—Left-hand section shows a 12″ steel shaft broken from fatigue of metal. Right-hand section shows pipe in center of 12″ steel shaft not closed up under hammer of 10 tons falling weight.

them and much money has been invested in fitting up the necessary apparatus. In order to have thorough supervision and control of every process, complete chemical and physical laboratories should be adjuncts of every forge that expects to do conscientious work. Records should be kept of the treatment of each forging as it progresses from one stage to another.

Let us run rapidly through the various processes which are now considered best practice in making steel forgings of high grade, and see if they overcome the defects which I have shown to have been so common in the past, and if they are tending in the right direction to meet the endurance which we have just seen is required of them in service.

Having carefully considered the service to which a proposed forging is to be put, the charge of raw material for the furnace is made up so that the finished product will have the proper chemical composition, which, from previous experience, is found to be most satisfactory. The elements, carbon, manganese, silicon, phosphorus and sulphur, all have an influence bearing not only on the working of the metal in the shops, but upon the strength of the forging in subsequent service.

[*To be continued.*]

FIG. 8.—Left-hand section shows a 12″ steel shaft broken from fatigue of metal. Right-hand section of 12″ steel shaft not closed up under hammer of 10 tons falling weight.

THE HOLOPHANE GLOBES, FOR EFFECTING THE BETTER DIFFUSION AND DISTRIBUTION OF ARTIFICIAL LIGHT.

[*Being the report of the Franklin Institute, through its Committee on Science and the Arts, on the invention of Messrs. Blondel and Psaroudaki of Paris, France.*]

[No. 1,945.] HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, October 6, 1897.

The Franklin Institute of the State of Pennsylvania, for the Promotion of the Mechanic Arts, acting through the Committee on Science and the Arts, investigating the merits of Blondel and Psaroudaki's Holophane Globes, submits the following report:

The invention submitted for investigation is one that pertains to the diffusion and distribution of light by means of a globe or shade placed around the source of the light.

The object of the invention is to secure diffusion of the light as well as such a form of distribution, that the light, usually lost by being sent off into the space above the horizontal plane passing through the source of the light, shall be distributed in the space below that plane and thus be made useful.

In order to secure these results, the principles of reflection and refraction are employed, and such a form is given to the contour of the globe as to make these principles available.

Whenever a beam of light strikes upon the surface of a medium that is not opaque, there are three physical results, namely, reflection, absorption and refraction.

In the globe under consideration, reflection and refraction are made use of to secure diffusion and distribution, and as the globe is made of a transparent material, the amount of absorption—which represents a loss—is reduced to a minimum.

The interior surface is made of a continuous series of vertical flutings, as is shown by *Fig. 1*, which represents a horizontal cross section through the middle of the globe. The function of these flutings is to secure a distribution normal to the direction of the incident light. This is practically in a

horizontal plane from a belt extending 15° to 20° on each side of a horizontal plane passing through the source of the light. The general character of this distribution is shown in *Fig. 1.*

Theoretical considerations require that the curve formed by the intersection of this inner fluting by a horizontal plane

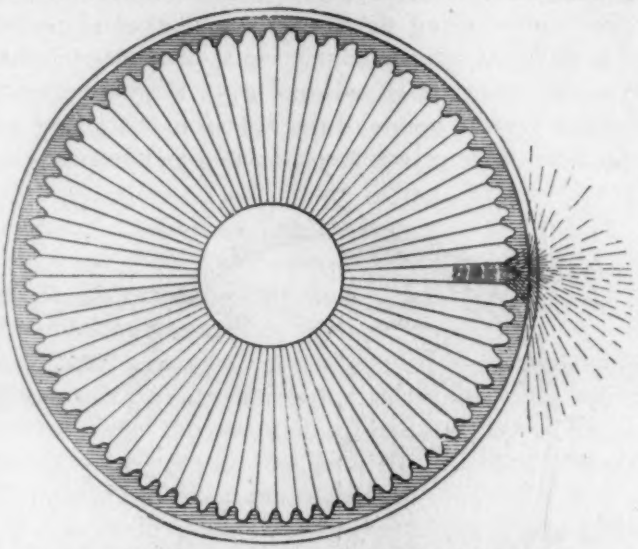


FIG. 1.—**Horizontal (center) section of holophane globe.**

should be a curve both convex and concave to the inside of the globe, the concave portion being about two-thirds the width of the curve, and that the angle made by two sides of adjacent grooves should be about 30°. Both of these requirements are met in the construction of the holophane globe, and hence the desired horizontal distribution is obtained.

An enlarged horizontal cross section of the inner fluting is shown in *Fig. 2.*

The external surface of the globe is made up of a series of circular grooves in a horizontal plane, extending over the entire surface of the globe.

In order to secure the best distribution of the light, each

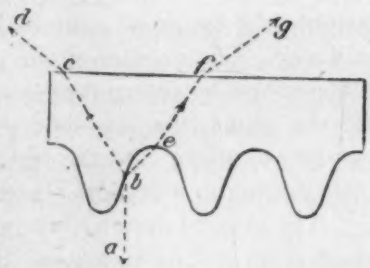


FIG. 2.

groove should, theoretically, be constructed according to the principles of geometrical optics, with reference to the relative position of the groove and the source of light. The method of determining the profiles of these grooves and ribs is as follows: The general contour of the globe and the location and size of the light source being determined, a number of points are taken at equal or approximately equal distances on the periphery, as shown in the left side of *Fig. 3*. Rays are drawn from the top and bottom points of the light source to these points, and the faces of the prisms are calculated geometrically to dis-

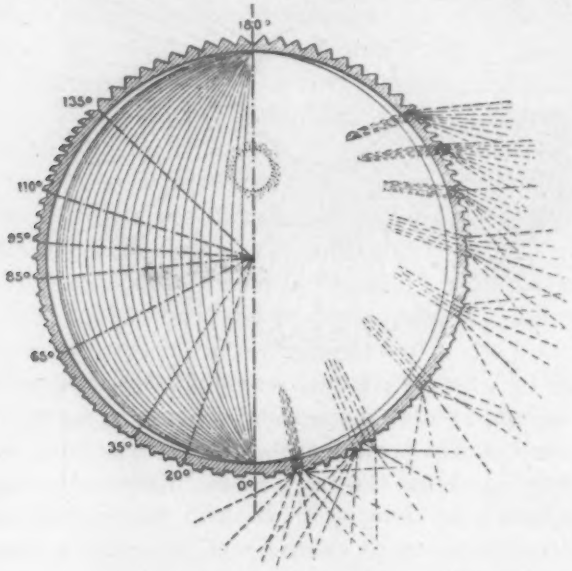


FIG. 3—Vertical section of holophane globe.

tribute the beam or cone of light in the most advantageous manner. The profiles of the prisms between these points are determined by interpolation. *Fig. 3* shows a vertical section of the globe, the left side showing the division into bands spoken of above, and the right side showing their effect upon distribution in a vertical plane.

The general design of the external grooves is shown in vertical cross section in *Fig. 4*. The external part of this section is seen to consist of four faces.

The face, *a b*, serves to throw the beam falling upon it below its original direction by refraction. The beam falling upon the face, *b c*, strikes at a greater angle than the critical angle, and hence is reflected downward and passes out the face, *d e*, where it is variously distributed by refraction.

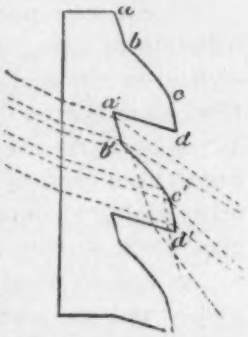


FIG. 4.

The face, *c d*, serves the same purpose as the face, *a b*, but as the beam strikes it at a different angle it passes out in a different direction. The opinion of the investigating committee, after having examined the theory of construction of the globe, and after having studied the results obtained from it, is that the inventors have succeeded in making such a combination of inner grooves, giving horizontal distribution by refraction, and mixed outer grooves giving vertical distribution by both refraction and reflection, that both diffusion and an improved distribution are satisfactorily obtained.

Upon examining the distribution of light by this globe, the investigating committee found that when the light from an arc lamp passed through the globe the effect upon a vertical screen showed a distinct cutting down of the amount of light passing in a straight line through the upper part of the globe and a definite increase of the light on a horizontal plane, and at all angles below that plane, the space vertically beneath the globe being well illuminated.

The fact that diffusion is secured is shown by the character of the shadows cast. When an opaque body is held near the globe there is practically no shadow on a screen a few feet away. As the body is moved toward the screen, a faint shadow having very indistinct outlines is thrown upon it.

This property of the globe has the effect of entirely doing away with distinct shadows of bodies near it that is so objectionable in the ordinary arc light.

In appearance the holophane is covered with bright points over its entire surface. Each one of these points is a source of

light, sending out its rays uniformly distributed, and since the number of these brilliant points is very great, covering the entire globe, the light coming from its surface is diffused.

Recent tests made by Prof. Lewes, of London, on the distribution of light from a Welsbach burner through different globes, as reported in the *Progressive Age* for December 15, 1896, show that in the angle between the horizontal plane and 45° below it, the use of the holophane globe increased the light from 12 per cent. to 13 per cent., while the best of a number of other globes examined gave a loss of 7·5 per cent. for a clear glass globe without any diffusion.

As a result of an examination into the construction of this globe, and an investigation into its practical working, the committee intrusted with this investigation believes that Messrs. Blondel and Psaroudaki have invented a globe that secures much better diffusion and more satisfactory distribution than any other globe known to its members; that the conditions of its manufacture are such that it can be supplied to the trade in commercial quantities; and that the invention has secured a distinct improvement in the diffusion and distribution of artificial light.

The Franklin Institute, for the reasons above stated, recommends the award of the John Scott Legacy Medal and Premium to Messrs. Blondel and Psaroudaki for their invention.

Adopted at the stated meeting of the Committee on Science and the Arts, held Wednesday, November 3, 1897. Award approved by the Board of Directors of City Trusts.

JOHN BIRKINBINE, *President.*
WM. H. WAHL, *Secretary.*

Countersigned,

JAMES CHRISTIE,
Chairman of the
Committee on Science and the Arts.

NOTE.

The above invention has been patented by André Blondel and Spiridion Psaroudaki, both of Paris, France, as follows:

Germany, March 16, 1893. No. 78,866.
France, September 30, 1893. No. 233,140.
England, October 12, 1893. No. 19,185.
Austria-Hungary, January 6, 1894. No. 48,988.
Belgium, March 13, 1895. No. 108,985.
United States, July 14, 1896. No. 563,836.

The committee of investigation, in its work, took occasion to refer to the above United States patent, to a paper entitled "Public Lighting by Arc Lamps," by André Blondel, Paris (pages 40-60); to the typewritten notes of a lecture by Prof. Elliott, of Pittsburgh, Pa., and to the *Electrical World* of January 2, 1897 (page 25).

The thanks of the Investigation Committee are due to Superintendent Mainwaring, of the Brush electric lighting station, through whose courtesy a comparison of the holophane with other globes was made.

SUPPLEMENTARY DATA.

The following brief abstract of the results of the experimental investigations of Herr H. Drehschmidt, chemist to the Municipal Gas Works of Berlin, is appended, partly because of their general value and interest as a contribution to the subject of modern methods of distributing light and partly as confirmatory of the conclusions reached in the foregoing report.

The work of Herr Drehschmidt was lately published in the *Journal für Gasbeleuchtung*,* under the title, "The Distribution of Light from Welsbach Burners when Used Alone, and when Used with Holophane and Diffusor Globes," and gave the results of his experiments to date, with the cause of the unexpected inefficiency of the Welsbach lights, installed on one of the principal thoroughfares of Berlin, in respect of uniformity of light diffusion. The author devised ingenious apparatus to

* See *Jour. f. Gasbeleuchtung*, Nov. 21, 1896.

measure in various planes this apparent irregular distribution, and made certain experiments with the "holophane globes" and other related devices for correcting the inherent defect of the Welsbach light. The abstract of this work herewith reproduced is confined to the comparative exhibit made by the naked lights, and the same provided with the holophane globes, viz.:

"When the Stralauer-Strasse, Berlin, came to be lighted with incandescent gas lamps the result was, in spite of the high candle-power of the lamps, that the lighting made no great impression of brilliancy; the street pavement seemed, on the contrary, to be rather dark, and only the walls of the houses at the level of the lamps were brightly lit up.

"It may, perhaps, be the case that the green tint of the Welsbach light is not absolutely negligible, but the principal cause must be looked for elsewhere. On the other hand, the light radiating from a Welsbach burner is not equally distributed in all directions, taken with reference to a horizontal plane passing through the burner, and underneath the burner it is distributed in a fashion which is unduly unfavorable to the purpose of illumination. Furthermore, it was found that the reflectors used in the Stralauer-Strasse lamps contributed little towards making up for this defect in the Welsbach light.

"In the laboratory of the Municipal Gas Works in Berlin investigations have been made for some considerable time past with regard to the distribution of light from incandescent burners, both when used alone and with the aid of globes and reflectors. In these investigations I used by preference a mirror-reflecting apparatus specially designed by myself.

"The light radiating from the burner at different angles strikes a mirror, invariably at 45°, and is reflected horizontally along the axis of the photometer. The burner can be brought into all the different required positions by the simple turning of an arm, and it remains through this means at a uniform distance from the mirror, which moves at the same time as the burner does. The light passing downwards can be measured at all angles from 0° to 90° with the horizontal; that passing upwards can only be measured as far as 80°, since at an angle

FIG. 5.—Bare arc lamp.

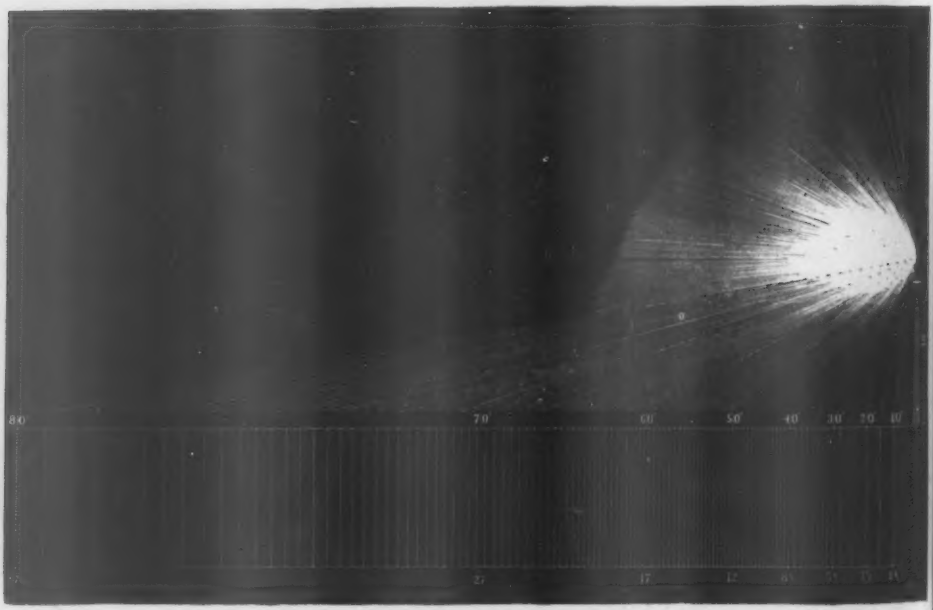


FIG. 7.—Bare Welsbach.

FIG. 6.—Holophane globe on arc lamp.

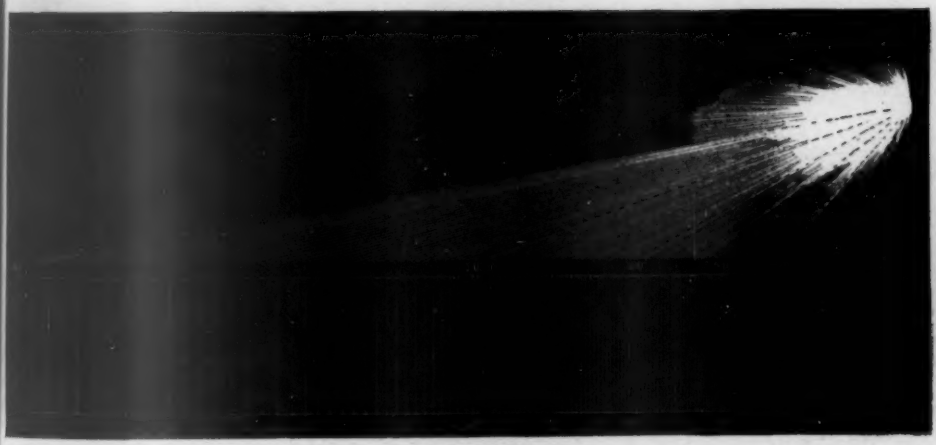


FIG. 8.—Holophane globe on Welsbach.

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of 90° with the horizontal the burner would be directly under the mirror, and the latter might probably be damaged by the hot gaseous products of combustion. The light sent upwards between 80° and 90° is, however, so small that even to neglect it altogether makes very little difference in the aggregate result. The measurements made with this apparatus take scarcely any more time and trouble than the ordinary photometric measurement of light in the horizontal direction.

"The incandescent gas burner used in these researches came from the German Incandescent Gas Light Company (Welsbach), and it gave, when fitted up with a fresh mantle from the same company, a light of eighty-five English standard candles (ninety-eight Hefner units)* after two hours' use, and of seventy candles (eighty Hefner units) after thirty hours' use, all at a pressure of twenty-five millimeters (0·984 inch), and a gas consumption of 3·638 cubic feet per hour. Since the illuminating power of the incandescent gas light was not constant, but diminished continuously as time went on, it was necessary, in order to make the results of different investigations comparable with one another, to set down in every case the illuminating value of the bare Welsbach lamp taken in a horizontal direction, as 100, and to state the values in other directions proportionately to this.

"By a bare Welsbach lamp is meant the Welsbach lamp without globe or reflector. Table A shows that there is a continuous decrease in the luminous intensity as we pass into the different directions lying below the horizontal plane of the lamp, and this decrease is more rapid the more nearly we come vertically under the lamp. Vertically under the lamp it is almost dark, for there the intensity falls to only 0·4 per cent. of what it is at the same distance horizontally. Above the horizontal plane the distribution of light is very similar, but the decrease is far smaller. The results show that the greater part of the light produced is sent upwards to about 20° above the

*** One English standard candle = 1·14 Hefner units; the Hefner unit being the light of a standard lamp devised by Von Hefner-Alteneck, the fuel used in which is acetate of amyl. This is the standard now mostly used by the German gas engineers.**

horizontal plane. In street lamps this light cannot be utilized in a downward direction by means of the ordinary reflectors. In order to be able conveniently to take off the glass chimney to clean it the reflector cannot be placed as low as would be necessary in order to catch the rays traveling at an upward angle of 30°, and thus about one-third of all the light produced by the lamp is completely lost for the purpose of street lighting.

"The rapid diminution of lighting power as we come under-

TABLE A.

ANGLES MEASURED FROM THE HORIZONTAL		BARE LIGHT	WITH HOLOPHANES (COMPOUND PRISMS)				
			TULIP NO.1	TULIP NO.2	CONE NO.3	CONE NO.4	GLOBE NO.5
	0°	100,0	90,7	123,9	104,6	113,5	70,3
BELOW	10°	96,2	99,8	119,7	106,3	116,3	91,8
	20°	88,4	105,6	100,6	98,8	104,2	109,5
	30°	77,0	104,3	90,0	88,1	85,1	110,4
	40°	63,3	94,8	68,2	75,5	63,3	94,9
	45°	58,6	87,1	59,0	66,1	51,9	84,2
	50°	50,6	78,7	50,8	60,5	47,2	74,0
	60°	32,4	62,1	40,3	46,6	43,9	58,8
	70°	14,3	48,9	31,8	40,8	43,2	48,2
	80°	3,5	40,9	29,8	40,8	40,1	48,2
	90°	0,4	33,2	23,7	38,1	28.9	44.1
ABOVE	10°	99,7	70,5	95,3	100,4	101,0	63,6
	20°	98,3	39,7	44,8	65,0	62,4	60,3
	30°	90,5	34,3	26,7	29,6	29,1	48,6
	40°	82,7	27,7	26,5	25,3	25,9	40,0
	45°	75 4	28,2	27,2	27,7	31,0	35,9
	50°	70,9	30,6	54,3	32,2	39,8	31,4
	60°	58,8	46,1	56,9	48,6	55,3	31,5
	70°	42,4	66,6	61,1	33,4	61,5	38,9
	80°	30,0	56,5	51,9	48,0	48,1	55,1

neath the Welsbach lamp, which is peculiar to this lamp, is not astonishing when we consider that the mantles, after a very short time, assume a form which is smaller above, and that any light sent from the upper portions of the mantle is obstructed in its path downwards by the wider lower portions. There are similar phenomena, however, even in the Argand flame.

"Herr Polis, of Aix, recently drew attention in the *Journal*

für Gasbeleuchtung to holophane and diffusor globes as good means of distributing light. I obtained, through the German Incandescent Gas Light Company (Welsbach), a number of holophane globes from the French Holophane Lighting Company, as follows:

"No. 1.—Tulip shaped, 150 millimeters (= 5·90 inches) high and 135 millimeters (= 5·42 inches) broad, with an upper opening of 125 millimeters (= 4·92 inches) and a lower of 56 millimeters (= 2·20 inches).

"No. 2.—Tulip shaped, 145 millimeters (= 5·71 inches) high and 140 millimeters (= 5·51 inches) broad, with an upper opening of 130 millimeters (= 5·12 inches) and a lower of 56 millimeters (= 2·20 inches).

"No. 3.—Cone shaped, 130 millimeters (= 5·12 inches) high and 110 millimeters (= 4·33 inches) broad, with an upper opening of 100 millimeters (= 3·94 inches) and a lower of 56 millimeters (= 2·20 inches).

"No. 4.—Cone shaped, 110 millimeters (= 4·33 inches) high and 105 millimeters (= 4·14 inches) broad, with an upper opening of 95 millimeters (= 3·74 inches) and a lower of 56 millimeters (= 2·20 inches).

"No. 5.—Globe shaped, with a diameter of 165 millimeters (= 6·50 inches), an upper opening of 76 millimeters (= 2·99 inches), and a lower opening of 56 millimeters (= 2·20 inches).

"The holophane globes develop a revolution in the distribution of the light from a Welsbach burner, as is shown by Table A, as well as by the graphic diagram hereto appended. On the whole, more light comes downward than goes upward; besides this, there is better distribution of light downwards instead of to one side; and even directly under the burner the intensity of the light is considerably increased. With the tulip-shaped holophane the amount of light passing downwards below the horizontal plane is increased by 29 per cent. as compared with the bare Welsbach lamp, and with the other holophanes from 17·2 to 26·9 per cent. The light passing upwards has, on the other hand, been diminished from 28·5 to 42·0 per cent. The total loss by absorption and reflection is thus very small, being only from 7·7 to 9·8 per cent."

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In conclusion, attention is called to accompanying diagrams, *Figs. 5* to *8*, showing the distribution of light on vertical and horizontal planes from a direct current arc lamp and from the Welsbach light.

The figures used for the arc lamp are those given by Blondel.*

The figures used for the Welsbach light are those given by Drehschmidt in his article on the "Utilization of the Welsbach Light," in the *Journal für Gasbeleuchtung*, previously cited.

The quantity of light given out within the angles was determined by the formula

$$Q = (sin.\ i_2 - sin.\ i_1)\ (i_1 + i_2)$$

as used by Drehschmidt. The number of lines drawn within the angles is proportionate to the quantities of light thus determined; the lines thus represent rays of light or "pencils" of equal intensity. The space where they run together, showing clear white, is approximately the curve of vertical distribution, corresponding to the one given by Blondel.† W.

THE ALL-WROUGHT STEEL PULLEY.

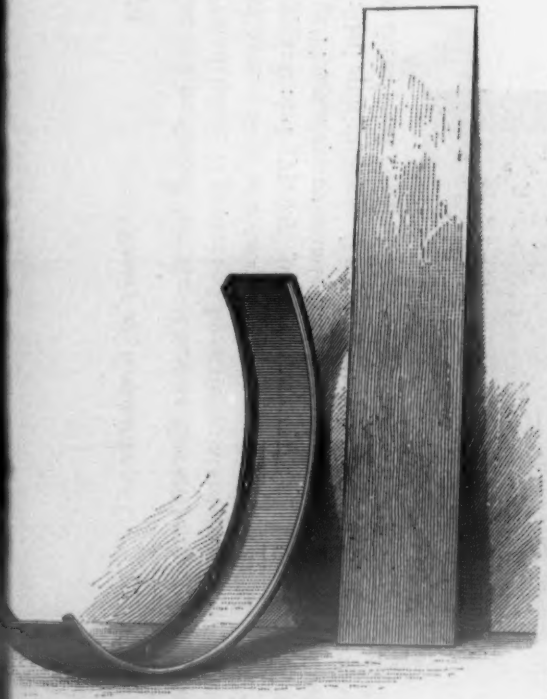
[*Being the report of the Franklin Institute, through its Committee on Science and the Arts, on the invention of Thomas Corscaden, of Philadelphia.*]

[No. 1,961.] HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, June 1, 1897.

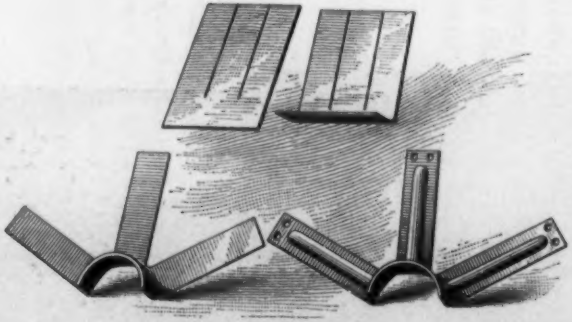
The Franklin Institute of the State of Pennsylvania, for the Promotion of the Mechanic Arts, acting through its Committee on Science and the Arts, investigating the merits of Corscaden's "All-Wrought Steel Pulley," reports as follows:

The all-wrought steel pulley designed and the manufacture

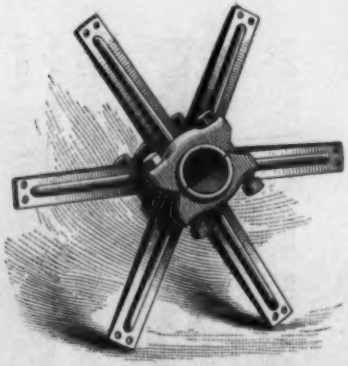
*See "Public Lighting by Arc Lamps," pp. 48, 50 and 51.
† *Ibid.* See *Fig. 50*, p. 45.



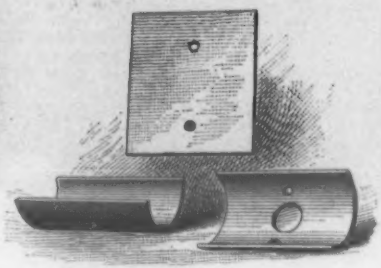
Blank and rim finished.



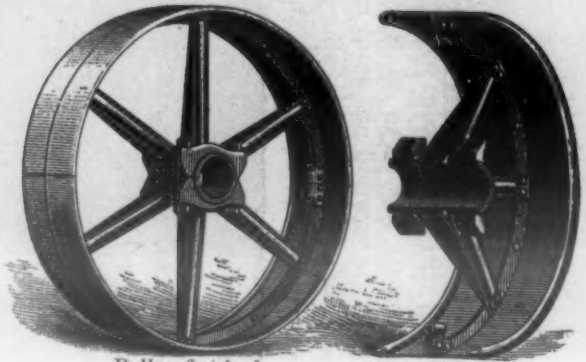
Making the spider or arms.



Spider finished.



Hub.



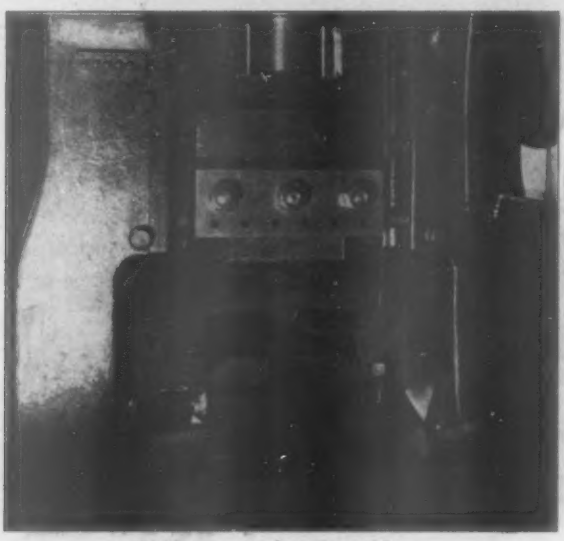
Pulley finished.

One-half of pulley.

Making the Corscaden all-wrought steel pulley.

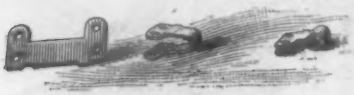
thereof perfected by Mr. Thomas Corscaden, of the city of Philadelphia, is protected by letters-patent to the inventor as follows: Nos. 474,546 and 474,547, May 10, 1892, and Nos. 575,106 and 575,107, January 12, 1897.

The pulleys are made in halves, and are such as are usually called split pulleys. They are made up from a number of parts of sheet steel cut from rolled plates. The rim is made in four



Die for convexing the spiders.

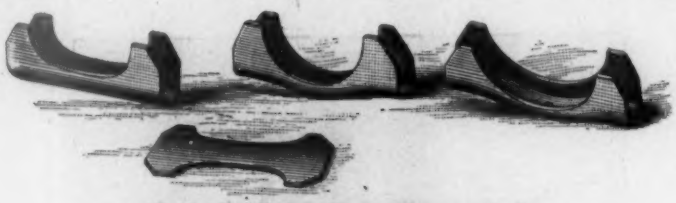
parts. The plate is cut up into long strips, the length of which is equal to one-half of the circumference of the pulley and the width equal to one-half of the width of the face plus an amount required to form a bead-moulding on the outer edge of the pulley and a flange web in the center of the pulley. Two of these plates are placed in the dies of a large hydraulic press, where a complete ring (in two halves) is formed, having a cylindrical bead all around the outer edge of the plates and a web flange on the outer edge. Two of these rim portions are placed back to back and riveted together through the web flange; then two of these pairs are brought together and are held in position by dowel-pins



Rim Clip.

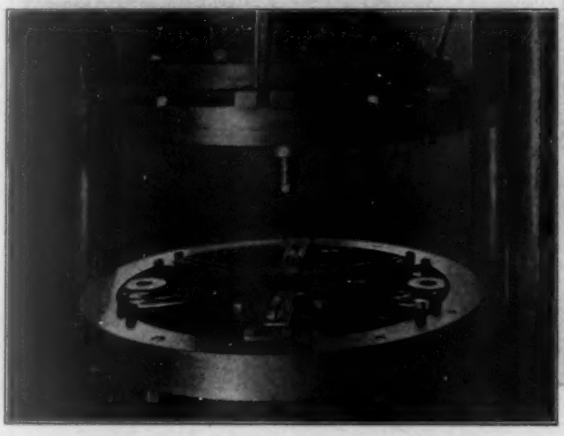
firmly fastened in the cylindrical mouldings at the edges, thus forming the complete rim of the pulley.

The spokes and hub are likewise formed in four parts; they are also cut from thin plates and are split part of their length into three parts, and the part that is not split turned at a right



Clip for holding pulley sections on shaft.

angle, which, after being perfectly formed, makes the hub. These parts are also placed in the hydraulic press, where they are compressed into form, making part of the hub with three half spokes. The half spokes have a conical groove pressed in them to stiffen them, and when two of these plates are placed



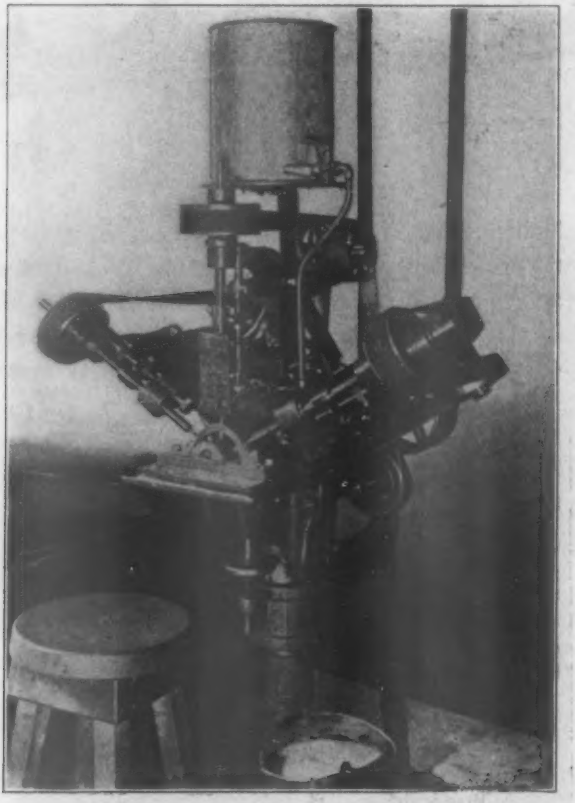
Die for forming the corrugations in spiders.

together and riveted they form a spider composed of one-half of the hub and three completed spokes; then the three spokes of the spider are riveted to the inner web of the rim, and thus one-half of the pulley is formed.

Cylindrical clamps are riveted to the web at both ends of

the section. The halves of the pulley are now placed together and firmly secured by bolts passing through the cylindrical clamps. They are held firmly in circular alignment by the dowel-pins fastened in the bead moulding at the edges of the rim.

The hub is completed by cutting clamps from the plates of



Machine for drilling spiders and hub-shells.

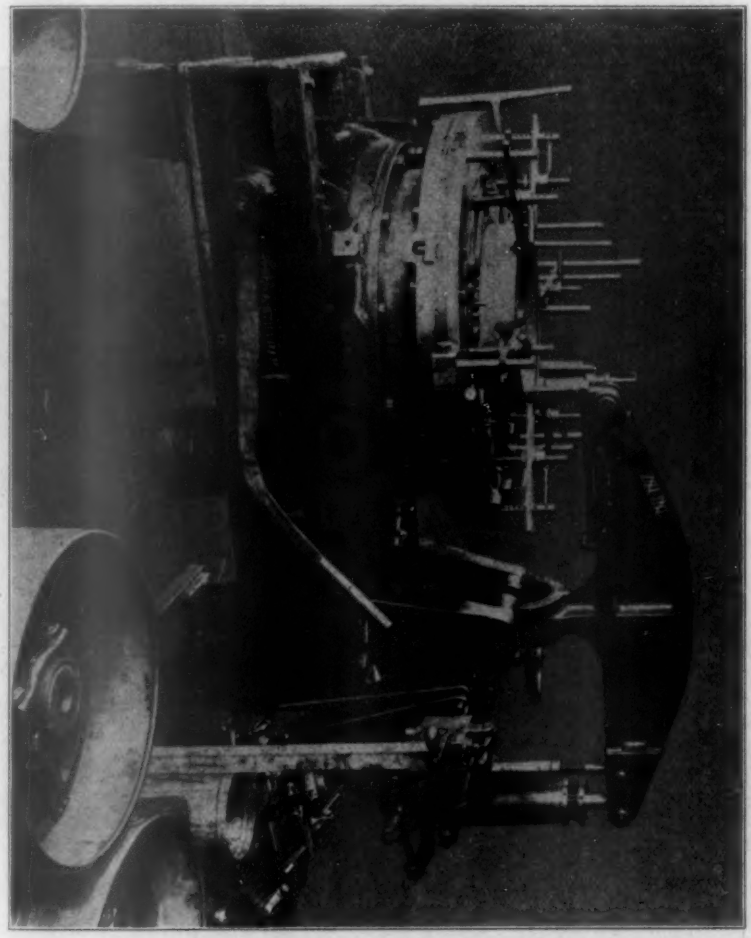
steel and forming them into U-shaped sections, the edges having been cut to fit around the half hub. A pair of these clamps are bolted together around the hub portion of the spider, thus holding the pulley firmly to the shaft.

During the process of manufacturing, the half rings, after being formed in the dies, are passed through bending rolls one

Hydraulic rim-forming machine. Cones the rim, forms the flange, and rolls the bead at one operation.

Hydraulic machine for riveting spider-arms to rims.

or more times until a perfectly formed semi-circular rim is produced without strain. The parts constituting the hub and spokes are annealed, whereby all strains are removed from these sections.



Hydraulic machine for riveting spider-arms to rims.

The different parts being cut from the plates with punching dies are so nearly alike that they are interchangeable, and when the pulleys are assembled they are nearly balanced, more so than cast-iron pulleys usually are.

The pulleys are very light, so much so that one man can

put a 36-inch pulley upon a shaft and secure it thereto without assistance.

The American Pulley Company, owners of the patents, are now manufacturing pulleys from 6 to 24 inches in diameter, with faces from 2 to 12 inches in width, and they are now building machinery to manufacture all desirable sizes up to 60

Polishing machine.

inches in diameter. The hubs of all sizes of pulleys are made to fit the larger sizes of shafting, for which they are likely to be used, and bushings are furnished to reduce the bore to fit the smaller sizes.

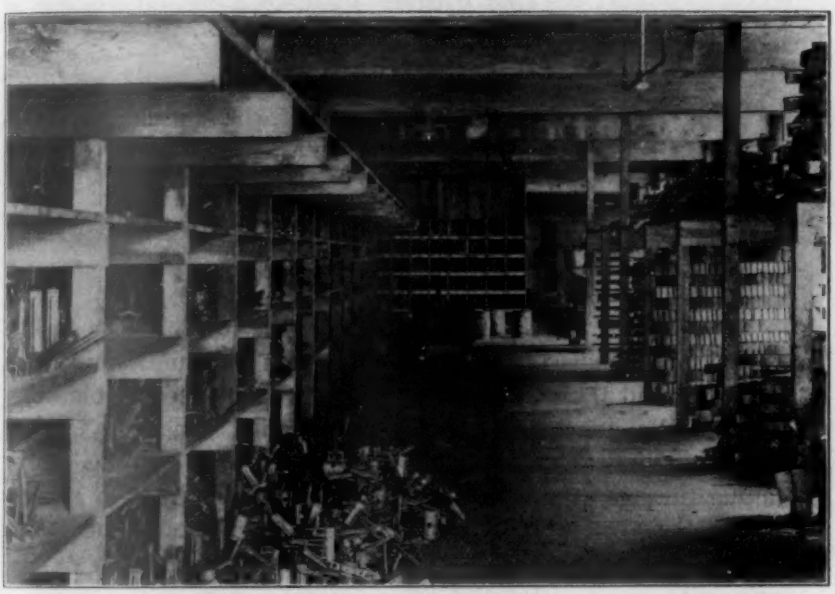
Keys in the shafting or set screws in the hub are not usually employed with these pulleys, but are furnished when required.

The pulleys are usually secured to the shafting with the clamping device above described.

The pulley is the lightest one known, its weight being only one-third of cast-iron pulleys of corresponding sizes, which the new construction notably surpasses in strength.

The price at which the new pulleys are sold is comparatively low, being lower than cast-iron pulleys of corresponding sizes.

The committee charged with this investigation believes that Mr. Corscaden has brought the manufacturing of belt pulleys to a degree of efficiency never before reached, and that



Stockroom, showing parts of pulley ready for assembling.

the manufacturers using pulleys will be greatly benefited by his inventions, and that the energy displayed by the inventor in producing so good an article at a low cost and in quantities that will enable the manufacturers and dealers to carry in stock all desirable sizes of pulleys is most commendable, and the committee believes that Mr. Corscaden merits the highest award of the Franklin Institute for his ingenuity in designing and perfecting this pulley and the machinery and system for manufacturing the same.

In view of the facts above set forth, the Franklin Institute awards to Thomas Corscaden, of Philadelphia, the Elliott Cresson Medal.

Adopted at the stated meeting of the Committee on Science and the Arts, held Wednesday, September 1, 1897.*

Countersigned, JOHN BIRKINBINE, *President.*

JAMES CHRISTIE, *Chairman of the Committee on Science and the Arts.* WM. H. WAHL, *Secretary.*

THE SPECIFIC HEAT OF ANHYDROUS LIQUID AMMONIA.

BY

LOUIS A. ELLEAU, M.E., NEW YORK

AND

WILLIAM D. ENNIS, M.E., LONG BRANCH, N. J.

Concluded from Vol. cxlv, p. 198.

METHODS.

(1) *Preliminary Operations.* In previous determinations the ammonia had always been heated in the vapor of some volatile liquid. We concluded that, for uniformity, simplicity, and cheapness, it was preferable to surround it with melting ice, taking the proper precautions to prevent moisture from condensing on the surface of the holder. The method employed is believed to be somewhat original, but to involve no new principle.

Some doubt being expressed as to the purity of the samples of ammonia furnished, a small amount was drawn off into a beaker and allowed to stand in the open air. It appeared to be perfectly clear, and, upon complete evaporation, left only a trace of an oily residue, due to the process of manufacture. A distilling apparatus was then arranged, as shown in *Fig.* 5. The pipe connections were coated with a paste composed of

* For the use of the illustrations in this report the *Journal* is indebted to the *Iron Age*.

glycerine and litharge, which gave almost perfect security from leakage. In a short time two or three pounds of ammonia were condensed over from the stock drum, and a sample of the distilled liquid was found to present exactly the same appearance as the commercial. Upon the surface of both, specks of what appeared to be floating oil were seen. This impurity was contained in quantities too small to affect the result of the tests as given; and, as manufactured ammonia always contains it, the conditions of actual practice were more nearly realized than they would have been with C. P. ammonia.

The following standard test directions were followed in the tests for purity:

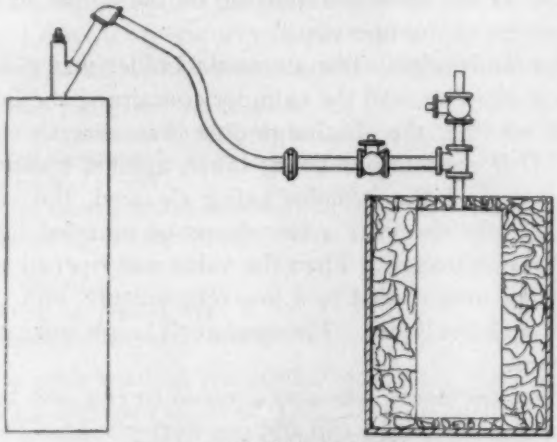


FIG. 5.—Distilling apparatus.

Anhydrous Ammonia Test Directions.—"To make the test, proceed as follows: Screw a short iron pipe, say 8 or 10 inches long, into the valve (it is best to loosen the valve stem after screwing on the pipe and to blow off a little of the gas so as to remove any dust or dirt that may have collected in the opening of the valve), slip the neck of the bottle over the pipe so that the latter projects into the bottle, open the valve a very little until the bottle is filled about one-fourth or one-half full, then remove the bottle, put on the cork with bent tube, and let the ammonia evaporate. As the evaporation may cool the liquid to such an extent as to cause it to freeze, it is well to hold

the bottom of the bottle in a bucket of water, moving it around to prevent ice from forming.

"After the ammonia has evaporated and the outside of the bottle has been wiped off dry, there should be no moisture left on the inside of the bottle. Of course, it is necessary that the inside of the bottle should be entirely dry and clean before drawing each sample. It is also necessary that the iron pipe should be entirely dry and clean before drawing each sample, as, after drawing samples, the evaporation of the ammonia cools the iron to such an extent that moisture from the air is condensed on the inside of the pipe.

"Caution should be used in drawing samples, as accident may occur by the ammonia spurting on the hands, in the face, or in the eyes of the operator."

Filling the Holder.—The ammonia holder was placed in a split block in a vise, and the cylinder containing the liquid was propped so that the discharge-pipe was directly over the holder. Due precautions being taken against moisture, and the other end of the cylinder being elevated, the valve was opened slightly to allow a few drops of mingled liquid and vapor to flow through. Then the valve was opened wide, the holder being now cooled to a low temperature, and the latter was filled with the liquid. The operator's hands were protected with gloves.

Some of the liquid was also allowed to run into an evaporating dish, in which the cap and pin were placed. The thread on the holder was then quickly smeared with the litharge and glycerine paste. The contents were allowed to evaporate until sufficient room was left for vapor and for the expansion of the liquid, when the cap was screwed down tightly. The pin was then driven in. By this arrangement it was possible to tighten the cap against the pressure within, and the final closing was effected instantaneously before the pressure had a chance to rise. The holder was placed at once in water at a temperature of about 36° C. as a test of its strength. Upon taking it from the water, after a reasonable time had elapsed, no leak was perceptible. Hydrochloric acid was used, as well as the ocular and olfactory tests, but it was not until two weigh-

ings had been made at an interval of sixteen hours that vapor was found to be escaping. Having made some previous attempts, we concluded that it was impracticable to make the holder perfectly tight, and determined to proceed with our test, the amount of loss being so small as to be almost imperceptible, and what loss there was giving the additional advantage of introducing a variable weight of ammonia into the thermodynamic equation.

(2) *Standardizing the Apparatus.*—The C. G. S. system was used throughout. Three Centigrade thermometers were employed, No. 1 being used for determining temperatures of the air only and graduated to half degrees, Nos. 2 and 3 being used in determining the initial temperature of the ammonia and the initial and final temperatures of the water, and graduated to tenths of degrees. They were standardized as follows:

Barometer, 761·35 mm., temperature	18°·3 C.
To reduce to grams at Paris divide by	1·00075.
Corrected barometer	759·57 mm.
Thermometer (1) read	100°·2 C. at boiling.
Corrected reading (protruding stem)	100°·38 C.
Temperature of boiling for 759·57 mm.	99°·99 C.
Difference	0°·39 C.
In melting ice, reading was	0°·31 C.
Average correction for (1) is then	—0°·35 C.

In the same manner the correction for (2) was found to be + 0°·05 C., and for (3), — 0°·37 C.

The calculation for the approximate size of calorimeter required was as follows:

Contents of holder, about one cubic inch.	
Lowest temperature of holder	32° F.
Highest " " "	72° F.
Range " " "	40° F.

If range in calorimeter is to be 5° F., the volume of water required is $40/5 = 8$ cubic inches.

The calorimeter was made of 2 inches diameter, 3 inches high. This gave a range even better than that assumed.

The English system was used in this calculation to avoid transformation for the workman.

(3) *Determinations.*—A silk thread was drawn through the

fine tube *C*, *Fig. 3*, the holder was attached to it and raised into the chamber *A*, when the cover *F* was clamped on the bottom. The thermometer was introduced into the tube *D*, care being taken to make the mercury column cross the axis of the sight-tubes *E E*. The tank was then filled with ice, which was replenished as rapidly as it melted. The cathetometer was adjusted so as to have its axis vertical, and the telescope was levelled and focussed on the mercury column, a light being placed on the other side of the sight-tube to illuminate the thermometer divisions. The time required for cooling was about four hours. There was no difference found between the second and third determinations, hence it was concluded that four hours were sufficient to bring the temperature of the ammonia down to that of the air chamber or within a fraction of a degree above 0° C. The actual times of cooling were, however, from five to nearly twenty hours.

When the desired period of time had elapsed water was introduced into the calorimeter, the rate of evaporation determined, and the temperature of the air and of the water read. The temperature of the air chamber was read through the telescope and estimated to the hundredth of a degree with the high magnifying power of the lens. The mercury was observed not to rise in the tube uniformly but to advance by short jumps, which would indicate the impossibility of getting more accurate readings. The influence of radiation between the water and the air was taken into account, as indicated in the calculation given.

Then, by a quick manipulation, the bottom plate of the cooler was removed and the holder lowered into the calorimeter. The time of beginning the experiment was noted. It required about two minutes to bring the calorimeter down to its lowest temperature. The holder was afterward dried and weighed.

DATA.

No. of test.	Time of cooling, hours.	Evaporation of water per minute, grams.	Average weight during test, grams.	Time of beginning test.	Temperature of air, C.	Initial temperature of water, C.	Immersion of thermometer.	Final temperature of water, C.	Immersion of thermometer.	Initial temperature of holder, C.	Time of ending test.	Temperature of water 5 minutes after test, C.	Degrees rise per minute, C.	Immersion of thermometer, C.	Weight of holder and contents, grams.
1	6	.001	126.460	1h49m45s	22°.3	24°.07	—0°.8	18°.52	1°.5	0°.31	1h53m45s	18°.76	0°.048	—.°.4	103.335
2	4	.006	116.354	4h16m45s	23°.0	23°.70	—2°.8	20°.02	—0°.3	0°.30	4h17m45s	20°.27	0°.050	—2°.5	92.971
3	16	.006	114.201	2h53m15s	22°.7	24°.60	—2°.5	20°.03	—0°.4	0°.71	2h55	20°.32	0°.058	—2°.8	92.936
4	5	.002	119.761	12h33m40s	23°.5	23°.75	—2°.5	17°.57	0°.	0°.51	12h35m15s	17°.77	0°.040	—2°.5	92.794
5	18	.008	121.482	4h22	24°.2	20°.39	—1°.4	21°.95	1°.	0°.34	4h24	22°.15	0°.041	—1°.5	92.793
6	5	.002	120.091	11h27m30s	23°.4	26°.66	—1°.3	18°.61	1°.	0°.65	11h29m30s	19°.08	0°.094	—1°.5	92.791
7	18	.002	125.816	3h25	24°.3	23°.37	—1°.1	18°.49	1°.3	0°.92	3h26m15s	19°.23	0°.152	—1°.0	92.788
8	5	.001	127.554	11h51m30s	22°.7	21°.89	—0°.8	18°.16	1°.7	0°.62	11h52m45s	18°.36	0°.040	—1°.0	92.787
9	18	.001	127.319	4h13m30s	22°.3	21°.68	—1°.3	19°.08	1°.5	0°.71	4h15m15s	19°.50	0°.084	—1°.4	92.785

Heat to det. therm. equiv.

Nine experiments were made. Ludeking and Starr made six, which we concluded was too small a number. Von Strombeck made eight. The difficulty of determining the specific heat lies largely in the fact that it is a "difference quantity," and hence a large number of tests is essential.

The entire data for the whole series of tests are given on the preceding page. The following factors remained constant throughout:

Weight of copper calorimeter	38·821	grams.
Water equivalent of "	3·6905	"
Weight of steel holder	81·001	"
Water equivalent of holder	9·4366	"
Weight of lead and litharge*	2·521	"
Water equivalent of same	0·07916	"
Weight of holder filled with water	103·235	"
Weight of water in holder	19·713	"
Weight of water that would be contained at 4° C.	19·757	"
Equivalent quantity of ammonia that would be contained at 4° C.	12·463	"

Note.—The specific gravity of the ammonia was calculated from D'Andreff's formula,†

$$d = \cdot 6364 - \cdot 0014\, t^{\circ},$$

where d = density, t = temperature Centigrade.

All temperatures given in the table are corrected for thermometric variation, but not for the protruding stem of the thermometer.

The ammonia tables given in Professor Wood's *Thermodynamics* were used in the calculations.

After the completion of the tests the ammonia was emptied from the holder and the latter filled with water, care being taken to screw down the cap to precisely the same position. The water was heated until slightly above the temperature of the room, the pin being removed, so that there was no danger of explosion when driven in. By weighing the holder under these conditions its cubic contents were ascertained. A determination of the specific heat of water was then made with a view to checking the accuracy of the methods used. The result obtained was ·997, an error of less than one-third of one per cent.

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* The quantity of paste used was so small that the error in including it with the lead is inappreciable.

† Trans. A. S. M. E., **10**, 641.

The water equivalent of the portion of the thermometer immersed in the calorimeter was found in the following two ways:

(1) *Method.*—Water was introduced into the holder and an experiment made with the water value of the immersed part of the thermometer as the unknown quantity. The following were the observed data:

Initial temperature calorimeter water	24°·07 C.
Temperature air	22°·30 C.
Immersion of thermometer	0°·80 C.
Final temperature calorimeter water	18°·52 C.
Immersion of thermometer	1°·50 C.
Weight of water in holder	19·713 grams.
Water equivalent of holder	9·516 "
Weight of water in calorimeter	87·648 "
Water equivalent of calorimeter	3·691 "
Rise of temperature in calorimeter in five minutes	0°·24 C.
Time required for experiment	3·25 minutes.
Initial temperature holder	0°·31 C.
Water equivalent of thermometer	*X*.

Calculations as follows:

Corrected temperatures by formula

$$\frac{n\,(T-t)}{6480} = \frac{24°\cdot87\,(24°\cdot07 - 22°\cdot30)}{6480} = °\cdot00679$$

$24°\cdot07 + °\cdot007 = 24°\cdot007 =$ corr. in. temp. of cal.

$$\frac{17°\cdot02\,(18°\cdot52 - 22°\cdot30)}{6480} = -°\cdot010$$

$18°\cdot52 - °\cdot010 = 18°\cdot51 =$ corr. fin. temp. of cal.

Radiation factor per min., $= °\cdot24 \div 5 = °\cdot048$ C. (In this case, the cooling at first was so rapid that the water was below the temperature of the air before any interchange of heat took place.)

Total radiation factor $= °\cdot048 \times 3\cdot25 = °\cdot156$ C.

Range in cal. $= 24°\cdot077 - 18°\cdot51 = 5°\cdot57$ C.

Range if no radiation, $18°\cdot20 - °\cdot156 = 18°\cdot044$ C.

Equation:

$$(9\cdot516 + 19\cdot713)\,18°\cdot044 = (3\cdot691 + 87\cdot648)\,5°\cdot716 + 5°\cdot716\,X.$$

From which $X = \cdot 98$, which is the water equivalent of the thermometer immersed to 1°·5 C., at a temperature of 24°·08 C.—an average value.

(2) *Method.**—Method of finding the water equivalent by weighing:

Suspend the thermometer, *Fig. 6*, by two threads, one at *A*, the end of the stem, and the other at *B*, where the stem joins the bulb. Hang the end *A* to one arm of a balance, and hang the other end from any convenient support.

Cool the bulb so that the mercury stands at *D*, some place near *B*, and weigh the end *A*. Then warm the bulb, and when the mercury has advanced some distance as *D C*, weigh the end *A* again.

Knowing the difference of weight of *A* and the amount of expanded mercury, we have sufficient data to calculate the weight of mercury in the thermometer.

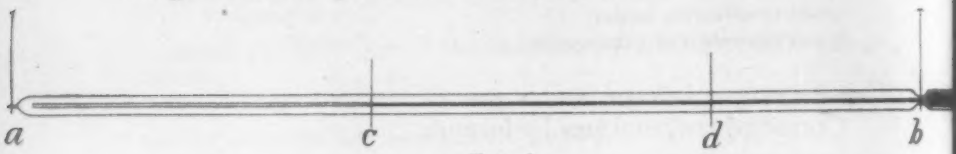

FIG. 6.

In the following let

A B be the length of the stem;

D A the original distance from the end of the mercury to *A*.

C A the final distance from the end of the mercury to *A*.

D A — *C A* = *D C* the distance the mercury has advanced.

w' the initial weight at *A*.

w'' the final weight at *A*.

$w'' - w' = w$, the increase in weight at *A*, due to the expansion of the mercury.

* This method of finding the water equivalent of a thermometer is due to the late Dr. A. M. Mayer.

Then the total increase in weight of the stem due to the expansion of the mercury equals

$$\left(\frac{AB}{\frac{CD}{2}+DB}\right)w$$

and the total weight of mercury in the thermometer is

$$\left(\frac{AB}{\frac{CD}{2}+DB}\right)w \div (R \times N) \qquad (a)$$

where R is the co-efficient of cubical expansion of mercury for 1° C., and N is the number of degrees between D and C.

For the thermometer used,

AB	= 35·3 cm.	
AD	= 26·4 cm.	AC = 13·4 cm.
$AD - AC = CD$	= 13·0 cm.	$AB - AD = DB$ = 8·9 cm.
w'	= 14·588 grams.	w'' = 14·601 grams.
$w'' - w' = w$	= ·013 grams.	
R	= ·0001818	N = 20°·5 C.
$R \times N$	= ·0037269	and (*a*) becomes

$$\left(\frac{35{\cdot}3}{15{\cdot}4}\right) {\cdot}013 \div {\cdot}0037269 = 7{\cdot}9 \text{ grams of mercury.}$$

Total weight of thermometer = 35·28 grams. 35·28 — 7·9 = 27·38 grams of glass.

Diameter of tube = ·62 cm.

Then volume of tube

$$= \frac{\pi}{4}(\cdot 62)^2 \times 35{\cdot}3 = 10{\cdot}67 \text{ cm.}$$

10·67 × 2·5 = 26·67 grams of glass in stem or from A to B, where 2·5 is the specific gravity of the glass.

27·38 — 26·67 = ·71 grams of glass in the bulb.

26·67 + 35·5 = ·755 = wt. of glass per cm.

If 4·4 cm. of the stem be immersed, then the total weight of glass immersed is

$$(4{\cdot}4 \times {\cdot}755) + {\cdot}71 = 4{\cdot}03 \text{ grams.}$$

Specific heat of glass = ·194.

Specific heat of mercury = ·0333.

Therefore the water value of the portion of the thermometer immersed will be

$$(4{\cdot}03 \times {\cdot}194) + (7{\cdot}9 \times {\cdot}0333) = 1{\cdot}04.$$

The other result being ·98, we assumed 1·00 as the water equivalent of the thermometer, which was always immersed to about the same depth, the bulb being in every case completely immersed in the water. The error could not be reduced to a much smaller amount than that given by this method, except by an extended series of tests, and, as the figure is not very important in the equation, the value 1·00 was considered sufficiently accurate.

The complete calculations for a single experiment are given below.

TEST NO. 9.

Weight of water and calorimeter at 3.57 P.M.	127·336 grams.
" " " " " 4.07 "	127·326 "
Evaporation in ten minutes	·010 "
" " one minute	·001 "
Time at middle of duration of test	4·14:23 P.M.
Evaporation for 4·14:23 — 3·57 = 17·27 min.	·017 gram.
Weight of water + calorimeter during test	127·319 grams.
Weight of calorimeter	38·821 "
Weight of water	88·498 "
Water equivalent of calorimeter	3·691 "
Water equivalent of thermometer	1·000 "
Total water value of calorimeter and contents	93·189 "
Weight of ammonia holder and contents	92·785 "
Weight of ammonia alone	9·263 "
Water equivalent of steel part of holder	9·437 "
" " " lead part of holder*	·079 "
" " " all metal of "	9·516 "
Volume of liquid ammonia in holder, 9·263 + ·6345 = 14·578 c.c.	14·578 c.c.
Total volume of holder	19·757 "
Volume of vapor space at beginning of experiment,†	5·179 "
" " same at end (found in same way)	4·564 "
One c.c. at °·71 C. weighs	·00361 grams.
" " 19°·08 C. "	·00663 "
Weight of vapor in holder at °·71 C., ·00361 × 5·179 = ·01870	·01870 "

*Litharge paste being included as lead.

† Neglecting expansion of liquid.

Weight of same at 19°·08 C. (found same way) . . ·03026 grams.
Difference in weight of vapor . . . . . ·01156 "
Heat used in vaporization, 295·4* × ·01156 . . . . 3·414 calories.
Initial temperature of water . . . . . 22°·61 C.
Final " " . . . . . 19°·08 C.
Initial " of holder . . . . . 0°·71 C.
Temperature of air . . . . . 23°·30 C.
Rise in temperature of water in five minutes after test . . . 0°·42 C.
Corrected initial temperature of water† . . . . . 22°·61 C.

$$22°{\cdot}61 + \frac{23°{\cdot}91(22°{\cdot}61 - 23°{\cdot}30)}{6480} = 22°{\cdot}61$$

Corrected final temperature of water . . . . . 19°·07 C.
Duration of test . . . . . 1·75 min.
Absorption of heat from air during cooling in the calorimeter,
$^{C}{\cdot}42 + 5 \times 1{\cdot}75$ . . . . . 0°·147 C.

Range of temperature in calorimeter if there had been no decrease due to the warming influence of the air,
$22°\,61 - 19°{\cdot}07 + °{\cdot}147$ . . . . . 3°·687 C.

Range in holder under same conditions,
$19°{\cdot}07 - °{\cdot}71 - °{\cdot}147$ . . . . . 18°·213 C.

The thermodynamic equation is, then,

$$(93{\cdot}189)(3{\cdot}687) = (9{\cdot}516 + 9{\cdot}263x)18{\cdot}213 + 3{\cdot}414,$$

whence x, the specific heat of the liquid ammonia,

$$= {\cdot}989.$$

The results for the nine experiments were as follows:

(1) 1·056	(2) 1·037	(3) 1·002
(4) 1·040	(5) 1·031	(6) 1·020
(7) ·983	(8) 1·028	(9) 0·989

The average result is 1·0206.

Certain known facts indicate the probability of the above result.

It practically agrees with the values deduced by Prof. Wood, his formula giving, for the conditions under which the experiment was made, ·98.

Ledoux's formula gives for a temperature of 10° C., which was about the average during our tests, the value 1·04.

The value 1·00 has been largely used by engineers, and has not appeared to be greatly in error.

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* Average heat of vaporization between initial and final temperatures of holder. Formula,

$$T + \frac{n(T-t)}{6480}, \text{ where } \begin{cases} n = \text{number of degrees protrusion.} \\ T = \text{temperature of water.} \\ t = \text{temperature of air.} \end{cases}$$

An average of all previous determinations gives (see page 194) 1·01.

The specific heat of superheated ammonia is ·506 as against ·48 for steam gas, an increase of 5 per cent. Our value for the liquid is 2 per cent. greater than for that of water.

The determination was made, as will be seen from the data, when the temperature of the ammonia ranged from about 0° C. to 20° C. This is nearer the temperatures of actual practice than Von Strombeck's of 60° C., or even of Ludeking's and Starr's of 40° C. The last-named investigators made three additional experiments with melting ice as a cooling medium, but so little is said of them, and that little is so indefinite that it is impossible to judge of the work intelligently.

We should suppose that a determination made when the iron shell was cooled in direct contact with the ice would be very approximate indeed.

The specific heat is undoubtedly variable, like that of water. In ordinary commercial calculations, the value for water is considered to be unity for all temperatures; and for such purposes that of ammonia may also be taken as constant.

The following table shows roughly that the value should increase with the temperature:

Authority.	Temperature at which exp. was made.	Specific heat.	Specific heat by theory.				
			Ledoux.	Zeuner.	*Wood.	†Wood.	‡Wood.
Von Strombeck	45° C.	1·229	1·17	1·38		1·17	·96
Ludeking and Starr	40° C.	·886	1·14	1·34		1·17	·97
Elleau and Ennis	10° C.	1·021	1·04	1·10	·98	1·14	1·04

* See formula given above, page 193.
† *Trans. A. S. M. E.*, **12**, 136. C = 1·12136 + ·000438 T.
‡ *Trans. A. S. M. E.*, **10**, 645. C = 1·096 — ·0012 T.

Prof. Wood's first formula makes the variation downward in one part of the scale and upward in another part, which corresponds with Prof. Rowland's law of variation for water.

To state an experimental value obtained by these methods

to five decimal places, even as an average, seems to be far beyond any accuracy which the data will warrant.

The "greatest possible error" is large, because of some of the insufficiently-determined constants. When the latent heat shall be conclusively and accurately established, a revision of these caculations might make a very small difference in the result.

If we assume all errors to be in the same direction, and as large as possible, as follows:

Error in weighing	·001 grams.
Error in reading temperatures	0°·01 C.
Error in tabular heat of vaporization	5 per cent.

we have, for the variation of result, 6 per cent. The maximum probable error is then about 3 per cent. The average of nine determinations is then reliable within one-third of one per cent.

From the evidences given in the data and the above remarks, our conclusion is that the experimental specific heat of anhydrous liquid ammonia is 1·02 at 10° C., a practical confirmation of the theories of Zeuner, Ledoux, and Wood. For those who prefer to use the variable value, Ledoux' formula, with the first constant reduced, is convenient:

$$x = ·9834 + ·003658\ t° \text{ C.}$$

THE FRANKLIN INSTITUTE.

Annual Meeting, Wednesday, January 19, 1898.

TESTS OF THE SYNCHRONOGRAPH ON THE TELEGRAPH LINES OF THE BRITISH GOVERNMENT.

THE WHEATSTONE RECEIVER OPERATED BY THE ALTERNATING CURRENT IN TRANSMITTING INTELLIGENCE.

BY

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AND

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(*Concluded from vol. cxlv, p. 178.*)

EXPERIMENTS WITH THE ARTIFICIAL CABLE.

Opportunity was presented for preliminary tests of this method of transmitting signals over the artificial cable belonging to the British Post Office Department, and of making direct comparisons of the alternating-current method with the present Wheatstone system over the identical cable. These trials were made on August 21, 1897. This cable, which represents to within 1 per cent. the real cable such as is used from England to the continent, to Ireland, the Channel Islands, etc., is made in 60 sections of three knots each, making a total of 180 knots or 207·5 miles. Each section has K equal to 1 microfarad and $R = 33$ ohms, making total $K = 60$ microfarads and total $R = 33 \times 60 = 1{,}980$ ohms, and total $KR = 118{,}800$. The cable is of the type in which the distributed capacity is obtained by condensers placed at regular intervals along its length.

Through this cable, with a voltage of 110, messages were sent at a frequency of 93·6 or 187·2 alternations per second, using the synchronograph and the chemical receiver. The next experiment was with the Wheatstone system transmitter

and receiver, using 100 volts constant potential, and a speed of 120 words per minute equivalent to 72 complete waves per second was reached by the post office officials. Since the speeds vary inversely as the squares of the lengths, a frequency of 93·6, for example, over the 180-knot cable, corresponds to 210·6 or 421·2 alternations per second over a cable of 120 knots in length.

The cables from England to the continent are not at present operated by the Wheatstone system, although by so doing the speed would undoubtedly be increased; but the Hughes system, by a present international agreement, is employed. By the Hughes system the messages are received printed ready to be delivered. The continental cables are operated at about 100 words per minute by this system.

EXPERIMENTS SUNDAY, AUGUST 22, 1897.

With the experience already gained and the constants of the Wheatstone receiver measured a wider range of experiments was planned for this date, which were to include tests over each line for speed as follows:

(1) Wheatstone transmitter and receiver.

(2) Synchronograph and Wheatstone receiver.

(3) Synchronograph and chemical receiver.

Two other lines were made up for this date, which, being used both with and without earth, were equivalent to four separate lines as before, making eight lines tested in all with a total *KR* for the longest line equal to 261,215. The constants for the first line used on this date are given in the following table:

Section.		Mileage.		Total R.	K.		Total K.	KR.
From	To	Open.	Covered.	B. A. Units.	Open.	Covered.		
London	York	197·63	16·87	1738	2·96	4·55	7·51	13052
York	Leeds	28·25	2·50	500	·44	·67	1·11	555
Leeds	London	198·11	2·83	545	2·57	·76	3·33	1815
		423·99	22·20	2783	5·97	5·98	11·95	33257

This line had a measured resistance by the Wheatstone bridge just prior to the tests of 2,799 ohms.

From long experience in the British service the basis which is there used to calculate the number of words per minute in terms of complete cycles of current by the Wheatstone system is 36 complete cycles = one word, or ·6 of a complete cycle of current per second equals one word per minute. This basis has therefore been used throughout in calculating the comparative speeds, using the synchronograph with the Wheatstone receiver, so that the comparative results given are independent of the length adopted for a dash or indeed of the particular code employed. The Wheatstone instruments were in all cases operated by operators of the telegraph department.

York line, with no earth, total $KR = 8{,}314$.

Synchronograph and Wheatstone receiver sent 666 words per minute, corresponding to 266·4 complete waves of current per second. The coils of the receiver were joined in parallel, giving an $L = \cdot 875$ henry and no condensers were used. Voltage, 175. In this line, where the mechanical limit of the Wheatstone receiver is reached before the speed is limited by the total value of KR of the line, it is seen how the perfect regularity, equality and shape of the sine waves materially increased the upper limit of the Wheatstone receiver.

Synchronograph and Chemical Receiver.—With this combination the alternator was run higher than before, until a frequency of 723 was attained, or 1,446 single impulses per second or 86,760 per minute.

York line with earth—total $KR = 33{,}257$.

Wheatstone transmitter and receiver sent 360 words per minute with a voltage of 100. Synchronograph with Wheatstone receiver sent 540 words per minute, voltage 200. Receiver coils in parallel $L = \cdot 875$ and condenser shunt across the coils of ·725 microfarads. No limit was obtained in this experiment.

The longest line as yet tested, of 1,097 miles, was then made up with data as given in the table below:

Section.		Mileage.		R.	K.		Total K.	KR.
From	To	Open.	Covered.	B. A. Units.	Open.	Covered.		
London	Aberdeen	499·56	35·50	6020	7·79	9·58	17·37	104567
Aberdeen	Glasgow	147·19	3·86	1805	2·30	1·04	3·34	6029
Glasgow	London	402·72	8·74	1075	6·28	2·36	8·64	9288
		1049·47	48·10	8900	16·37	12·98	29·35	261215

Route.—London to Aberdeen *via* York and Edinburgh, and return to Glasgow and Leeds. A portion of the line north of Edinburgh was iron wire upon the same poles, going and returning.

Aberdeen line no earth total $KR = 65{,}304$.

Wheatstone transmitter and receiver sent over this line 185 words per minute, voltage 100.

Synchronograph and Wheatstone receiver sent over this line 540 words per minute, voltage 215, coils in parallel.

Synchronograph with chemical receiver sent at frequency of ·723 or limit at which it was safe to run the alternator. This result was higher than expected from the approximate law indicated by the preceding trials, and a reason for this was sought. The line was broken at Aberdeen and records were still received. It was then restored at Aberdeen and broken at Glasgow, when as before no record was obtained. The cause of this was thought to be the inductive effect of that portion of the line beyond Glasgow, where the iron wires going and returning were unavoidably upon the same poles.

Aberdeen line with earth total $KR = 261{,}215$.

Wheatstone transmitter and receiver sent over this line 46 words per minute, voltage 100.

The synchronograph and Wheatstone receiver sent over this line 135 words per minute, voltage 85, coils in series $L = 3{\cdot}46$, condenser of 5·75 microfarads shunted across coils.

The results of the foregoing experiments are given in tabulated form in *Fig. 15*.

THE TRANSMISSION OF INTELLIGENCE IN GREAT BRITAIN.

One of the reasons for going to England was to become conversant with their method of conducting the telegraph and

No.	Line	Miles open	Miles covered	Miles Total	Total R	Total K	Total KR	Wheatstone (trans.) Words per min.	Synchronograph & Wheatstone Receiver Words completed per min.	Synchronograph Clem. Receiver Words completed per min.	Generator revs per min.	Generator No. poles	Generator Voltage Line	Wheatstone Coils per set	Wheatstone Condenser Shunt Series	Wheatstone Subsidiary Z
1	York & Perth	123.89	22.20	146.09	2798	2.91	134	600.	24.							
2	" "	"	"	"	"	"	"									
3	" "	"	"	"	"	"	"			723						
4	York & Perth	"	"	"	"	11.9	33,257	360.	144				100			
5	" "	"	"	"	"	11.9	"									
6	" "	"	"	"	"						1293	18	175	parallel	725	.576
7	Newcastle & Perth	598.93	31.91	630.84	4320	4.72	20,380						200	"	"	"
8	Newcastle & Perth	"	"	"	"	1.19	81,518			652	2801	30				
9										165	550	18				
10	Glasgow & Perth	120.56	44.04	164.60	3260	6.03	19,771									
11	Glasgow & Perth	"	"	"	"	24.2	127,012			652	2601	30				
12																
13	Aberdeen & Perth	204.47	44.10	248.57	5300	7.35	45,344	115	74.0							
14	" "	"	"	"	"	"	"						100			
15	" "	"	"	"	"	"	"			540	216		215	parallel		175
16	Aberdeen & Perth	"	"	"	"	20.3	261,215	46	11.4	723	2192	30				
17	" "	"	"	"	"	"	"						100			
18										135	54	54	360	18	85	Series 575	146
19																
20	Cork	287.5		287.5	5910	60	171,300	120.	48				100			
21	"	"	"	"	"	"										
		● Wheatstone work			● Synchronograph work						93.6		1245	18	110	

FIG. 15.

telephone business in conjunction with the general postal service in a country where these three departments are under the control of the Government.

In the prosecution of this as in the experiments themselves every facility was afforded by the Government officials.

It is recognized that to draw correct conclusions upon the general subject of the transmission of intelligence requires men of experience in dealing with such matters, who give the subject their attention for a considerable period. Some of the principal facts, however, seem to be so clearly defined in their relation to others that we feel warranted in making some observations thereon.

In the previous paper some data were given concerning the transmission of intelligence in the United States and in a similar manner will follow the data for Great Britain. This is shown in graphical form in *Fig. 16*, where seven curves are given, two for the total revenue and expenditure of the postal service in the United Kingdom and two for the revenue and expenditures of the telegraph department of the United Kingdom, one for the total number of letters only delivered in the United Kingdom, and one giving the number of telegrams forwarded from telegraph offices in the United Kingdom, and the seventh gives the per cent. of profit for the postal service.

The revenue from the postal service was about $26,000,000 in 1872, and increased gradually until, in 1896, it had reached $57,000,000. The expenses for this service in 1872 were about $19,000,000, and increased gradually until, in 1896, they were about $39,500,000. It is seen that the lines representing both revenue and expenditures are approximately straight, and that the revenue is invariably greater than the expenditure. In 1872 the per cent. of profit was about 37, and in 1890 it reached 55 per cent., while in 1896 it was 45·5 per cent. It should be understood that these amounts include the parcel post as well as the mail. The limit of weight which may be sent through the post office in this country is four pounds, but the parcel post of the British Government virtually does much business similar to that done by the express companies in the United States.

In 1896 the profit of the post and telegraph together was $17,600,00. The Select Committee of the House of Commons in 1888 dwelt upon the necessity of working in the main upon

business principles with a view to a profit on the transactions of each year, and added that the high business character of the Post Office Department was in no small degree due to the fact that it had been administered in this spirit and from this point of view.

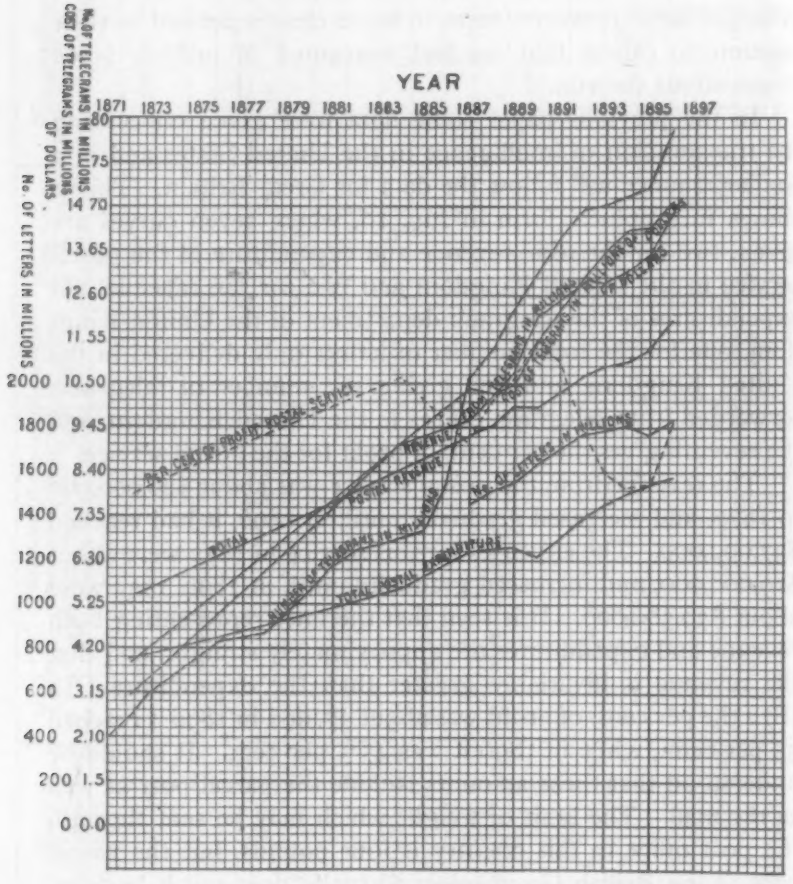


FIG. 16.

The number of letters delivered, not including post cards, was, in 1887, about 1,459,900,000, and in 1896 it was 1,834,200,000, the largest number.

Referring to the curves of telegraph revenue and expendi-

tures, it is seen that they each increase with approximate uniformity. In 1872 the revenue was about $18,200,000 and the expenditure about $14,500,000, while in 1896 the revenue was $69,700,000 and expenditure $70,500,000. These two curves nearly coincide and cross each other three times in twenty-five years, showing that the telegraph business is conducted on the whole to meet the expenses only and leave no profit. In some years the expenses are greater than the revenue, and the account shows a deficit. This has been the case for the last five years, but it has been gradually decreasing for three years, and in 1896 was only $168,000.

The number of telegrams forwarded from telegraph offices in the United Kingdom in 1871 was 9,850,177 and in 1896 was 78,839,610, and the curve representing this shows a continual increase from year to year. In 1896 the ratio of the number of letters to telegrams was 18·5.

The charge for transmitting ordinary telegrams is a half-penny or one cent per word, including the address. The minimum charge is six pence, or about 12½ cents, and the same price for any distance. The telegraph is used to a much greater extent for transmitting news in England than in any other country; for instance, in 1896, 5,915,646 telegrams were transmitted at the press rates for newspapers, clubs, etc. The average weekly number of words contained in these telegrams was about 13,650,000. The average length of each telegram is therefore 120 words. The explanation of this is found in the reduced rate given to the press after 6 P.M., which is at present but six pence per hundred words. This press matter is handled almost entirely by the Wheatstone automatic system, where automatic telegraphy is more advanced than in any other country in the world. There are as many as 477 sets of Wheatstone instruments in use in Great Britain, and for press messages pneumatic perforators are used and a number of duplicate strips are prepared at once, and thus the same press news may be sent out on eight or nine different lines from London at the same time. Many of the lines, which are ordinarily operated by hand, are equipped with Wheatstone instruments. These are switched in whenever the traffic for the particular

line becomes too great for hand transmission. They are also much employed for temporary lines where an unusual volume is to be handled in a short time, such as in sending the enormous amount of racing and sporting news required.

The telephone service in England is not entirely under the control of the Government. The trunk lines are so controlled and operated, leaving to private companies the service in local districts. Some of these trunk lines were transferred to the Government on the 25th of March, 1896, by an agreement with the National Telephone Company.

In a country where the three great branches of intelligence transmission, the mail, the telegraph and the telephone, are under one management, special advantages to the people are obtained which are not given when these departments are separated. In England messages may be telephoned:

(1) For transmission over the postal telegraphs and delivery as telegrams.

(2) For delivery as express letters.

(3) For transmission and delivery as ordinary letters.

The telephone may also be used for obtaining the services of post office express messengers.

As indicating the increased demands for communication between England and the continent the following extract from the last report of the Postmaster-General on the post office is given: "The large increase in the number of telegrams passing over the Government cables to the continent, and in the number of conversations on the telephone circuits between London and Paris, has rendered it necessary to consider the advisability of improving the means of communication. With the cordial co-operation of the German post office, experiments were made with a view to improve the carrying capacity of the cables to Germany by the method of duplex working, which has been employed with success on some of the Anglo-French cables; but, owing to the greater length of the Anglo-German cables, the results obtained were not sufficiently successful to justify the adoption of the system for practical working. Arrangements have now been made for the laying of three additional cables to the continent, two to France and one to

Germany. These cables, each of which will contain four conductors, will afford a much-needed relief to the traffic; and it is expected that this new cable to Germany will prove suitable for duplex working."

CONCLUSION.

The results of the experiments described show that the use of an alternating electromotive force, which does not rise suddenly and fall off as abruptly as is the case with that of most transmitters, but which rises gradually from zero to a maximum and falls again to zero as gradually, is the best kind of wave for use on actual lines with distributed capacities.

The synchronograph, which employs this kind of an alternating electromotive force made and broken always at the neutral points, has thus far proved to be better than other transmitters for the transmission of electrical waves over a given line at any speed, slow as well as fast. An examination of the various methods employed for increasing the speed of working on submarine cables shows not only that in such methods the waves are made of equal lengths, but that an endeavor is made to compensate for the square tops of the electromotive force waves of the transmitter, which is usually accomplished by the aid of condensers or auxilliary electromotive forces judiciously arranged in shunt circuits. In other words, the attempt is made by these devices to approximate a sine wave as nearly as possible, while the remedies which can be applied by such means at best only approximate this form of wave. The synchronograph adopts a smooth wave, approaching practically the sine wave in form as its fundamental principle, and supplies a simple method of using the waves generated by an alternating dynamo.

The substitution of the synchronograph for the Wheatstone transmitter on the identical lines, using the same receiver in each instance, showed a speed of operation by the synchronograph about *three-fold* faster, provided the mechanical limit of the receiver was not already reached. The causes of this great increase of speed are differences in the waves which pass through the receiver; since the only way by which the

identical receiver can distinguish between transmitters is by differences in the actual waves received. The waves of current passing through the receiver, which control its operation, are not of the same shape as the electromotive force waves of the transmitter. The current waves with the Wheatstone transmitter, for instance, have more or less rounded tops, but they maintain the same frequency as the transmitter, and waves for a dash are longer than for a dot. The current waves received from the synchronograph are not true sine waves in the receiver, even though the electromotive force is truly harmonic, but the frequency is the same as that of the generator and the waves are of equal lengths. The current wave from an alternator may approximate a sine wave very closely if the electromotive force is harmonic, and in fact if there is no leakage on the line it will be truly harmonic; or under some circumstances it may still be harmonic, provided there is a correct relation betweeen the leakage, resistance, inductance, and capacity. There are thus at least two causes which account for the slower speed with the Wheatstone transmitter, the fact that different frequencies or wave lengths are used in the transmitter and the departure from the sine form of wave.

Another cause for gain in speed by the synchronograph is the fact that higher voltage was permitted with it than with the Wheatstone transmitter, although it is difficult to estimate the precise amount of gain due to this. The reason for permitting different voltages lies in the construction of the instruments themselves; for with the synchronograph the contacts are made and broken at the zero points of the waves, and thus even when considerable capacity is present on the line, the amount of sparking is almost *nil* under circumstances when the Wheatstone transmitter would produce a powerful spark owing to the sudden application of the full voltage.

A fact which seems to point to the conclusion that the gain is due to the use of the sine form of wave rather than the adoption of uniform wave-lengths is the following: The experience with the Wheatstone system shows that the use of the condenser compensation before mentioned practically doubles the speed attainable on any given line by equalizing in some meas-

ure the line charges for the dash and the dot. This compensation is so perfect that the substitution of dots for dashes so as to make all waves of equal length and duration increases the attainable speed by about 5 per cent. only. The only difference remaining is the shape of the electromotive force wave when nothing but dots are used, so that it appears that the greater part of the gain is due to the use of the approximate sine wave.

Instead of comparing the speeds obtainable by the different transmitters on identical lines, another way of presenting the same facts is by the comparison of lengths and kinds of lines which permit the same speed with the two transmitters. This comparison is illustrated by the curves in *Fig. 17*, where the abscissæ represent miles of line and the ordinates represent words per minute on the basis of 36 complete waves per word as used in the English service. Seven curves are shown.

(1) The Wheatstone speed over iron wire of 400 pounds per mile; $r = 14$ ohms, per mile; $k = \cdot01573$ microfarads per mile.

(2, 3 and 4) Wheatstone speeds over copper wires of 200 pounds per mile; $r = 4\cdot45$; $k = \cdot0150$; and of 400 pounds per mile; $r = 2\cdot225$; $k = \cdot0156$; and of 800 pounds per mile; $r = 1\cdot1125$; $k = \cdot0160$.

(5, 6 and 7) Synchronograph and Wheatstone receiver speeds over the same copper wires as for curves 2, 3 and 4 respectively.

Referring to the general equation for Wheatstone speeds already given, which is

$$K\ R\ W = c = \text{a constant},$$

if $m =$ miles of line, then $K = m\ k$, and $R = m\ r$ in which k and r are respectively capacity and resistance per mile.

Then

$$m^2\ W = \frac{c}{k\ r} = c' = \text{a constant},$$

which is the above equation when translated into miles instead of KR.

The equations of the above curves with numerical constants are:

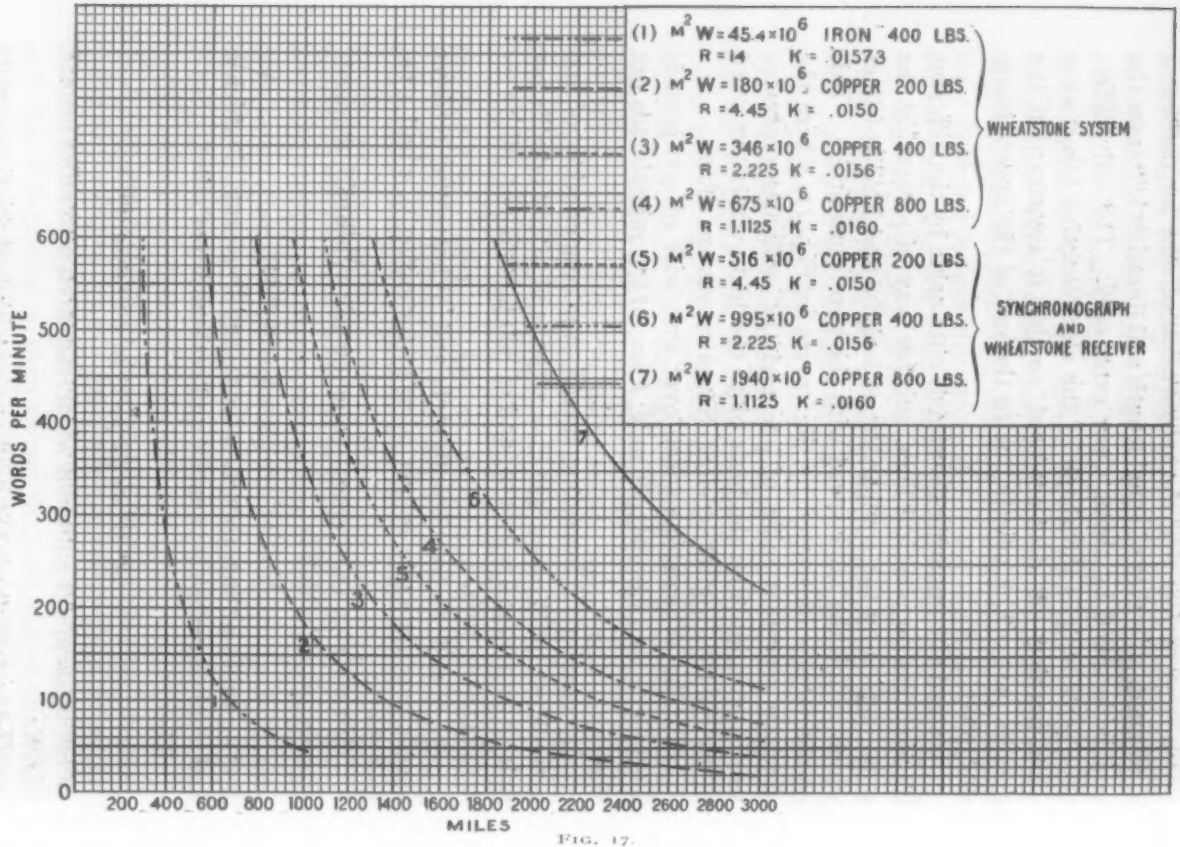

(1) M²W = 45.4×10⁶ IRON 400 LBS.
R = 14 K = .01573
(2) M²W = 180×10⁶ COPPER 200 LBS.
R = 4.45 K = .0150
(3) M²W = 346×10⁶ COPPER 400 LBS.
R = 2.225 K = .0156
(4) M²W = 675×10⁶ COPPER 800 LBS.
R = 1.1125 K = .0160
WHEATSTONE SYSTEM
(5) M²W = 516×10⁶ COPPER 200 LBS.
R = 4.45 K = .0150
(6) M²W = 995×10⁶ COPPER 400 LBS.
R = 2.225 K = .0156
(7) M²W = 1940×10⁶ COPPER 800 LBS.
R = 1.1125 K = .0160
SYNCHRONOGRAPH AND WHEATSTONE RECEIVER
WORDS PER MINUTE
0
100
200
300
400
500
600
200 400 600 800 1000 1200 1400 1600 1800 2000 2200 2400 2600 2800 3000
MILES

FIG. 17.

(1) $m^2 W = 45{\cdot}4 \times 10^6$
(2) $m^2 W = 180 \times 10^6$ } Wheatstone Transmitter and Receiver.
(3) $m^2 W = 346 \times 10^6$
(4) $m^2 W = 675 \times 10^6$

(5) $m^2 W = 516 \times 10^6$
(6) $m^2 W = 995 \times 10^6$ } Synchronograph and Wheatstone Receiver.
(7) $m^2 W = 1940 \times 10^6$

If c' is the constant for a given kind of wire with the Wheatstone system, and c'' the constant for the synchronograph and Wheatstone receiver, we write $m'^2 W' = c'$ and $m''^2 W'' = c''$ as the equations for the two cases. If the same number of words per minute are to be sent then $W' = W''$ and we have

$$\frac{m'}{m''} = \sqrt{\frac{c'}{c''}}$$

Since from experiment the ratio of c' to c'' for any given line is approximately 3, we have

$$\frac{m'}{m''} = \sqrt{3} = 1{\cdot}7.$$

That is, the synchronograph and Wheatstone receiver will operate on a line 1·7 times as long at the same speed as the Wheatstone system. The curves are limited as before at 600 words, which is the mechanical limit of the receiver. With copper wire 800 pounds per mile, the synchronograph can operate to the limit of the Wheatstone receiver any distance less than 1,800 miles.

The Wheatstone system using the same wire can operate to the same limit any distance less than 1,060 miles.

The synchronograph will operate the Wheatstone receiver at a speed of 215 words per minute on a line 3,000 miles long of 800 pounds copper. This is as high speed as is now used with Wheatstone in this country and no repeaters are required in the above case. The Wheatstone transmitter can send 75 words per minute on the same line.

The above calculation assumes the average line construction and climatic conditions in England.

Curve (1) exhibits the inferiority of iron as compared with copper wire; the curve shown is for 400 pounds iron wire.

FIG. 17.

The realization of an approximate sine wave of current at the receiver makes available at once the resonant method of augmenting the receiver current in a perfectly definite manner by the use of shunted condensers without changing the line current. In fact, knowing the inductance of the Wheatstone receiver, the proper condenser capacities were calculated for different speeds, and actual trials showed that the calculated capacities gave the best results.

With the Wheatstone waves such use of condensers is not followed, because resonance is not practicable with this kind of wave having different lengths and departing from the sine form. As before stated, the practice in England is to introduce into the line itself a large resistance around which the capacity is shunted and these adjusted by trial until the best results are obtained.

In view of these trials with the Wheatstone instruments it will be of interest to extend the experiments to other forms of instruments such as are now used or proposed for cable or automatic working. The gain in speed expected is less than with the Wheatstone system, since in long cables the transmitters used already employ waves of equal lengths.

It was interesting to observe whether a high frequency current, such as was used in these experiments, passing in a continuous loop of a thousand miles through a thickly-settled country, would cause any material disturbance in the telephone circuits of the region, but no such disturbances were reported, although orders were given for this to be noted.

It is believed that the Government control and operation of the telegraph would prove a great benefit to the people of the United States. The natural relation between this service and the general postal service requires that they should be under the same department for the most efficient and economical management.

ELECTRICAL SECTION.

Stated Meeting, October 26, 1897.

THE AMERICAN ELECTRIC METER.

By Wm. Dennis Marks.

The mechanism of this meter is so elementary in character that the accompanying illustration of a twenty-two-light meter requires but little explanation. The meter consists in the three-wire system of two solenoids and cores placed above a

Marks' electric meter.

self-starting pendulum actuated by the electric current. The pendulum, by means of a cam, raises a pawl on a ratchet wheel to a uniform height each stroke. The solenoids, by means of their cores, shift the angular position of a pendant arch attached to their axis so as to permit this pawl to drop along the ratchet wheel a number of teeth proportional to the cur-

rent passing through the meter. Thus, at each stroke of the pendulum, the load in ampères passing to the consumer is by means of the ratchet wheel and the dial register, measured and added up in ampère hours. That is all there is of the meter, save a pointer and scale showing through the glass the ampères passing. The interior mechanism is supported by a brass frame similar to that of a Yankee clock, and the case is cast-iron, thus acting as a magnetic shield, and preventing tampering with the meter by means of magnets on the outside.

CORRESPONDENCE.

A CONTRIBUTION TO THE HISTORY OF THE ART OF PHOTOGRAPHING LIVING SUBJECTS IN MOTION, AND REPRODUCING THE NATURAL MOVEMENTS BY THE LANTERN.

To the Editor of the Journal of the Franklin Institute:

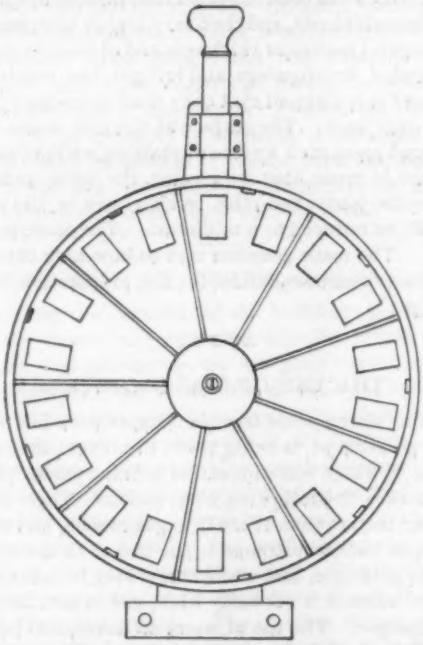
SIR:—Among the earliest public exhibitions of photographs taken from living subjects in motion projected by the lantern upon a screen, was that given at an entertainment held in the Academy of Music, in Philadelphia, on the evening of February 5, 1870,* and a repetition of this exhibition was made before the Franklin Institute at its next following monthly meeting, on March 16th, by the writer.

The subjects exhibited embraced waltzing figures and acrobats, shown upon the screen in life-size, while the photographic images were only ¾ inch in height. At that day flexible films were not known in photography, nor had the art of rapid succession picture-making been developed; therefore, it was necessary to limit the views of subjects to those that could be taken by time exposures upon wet plates, which photos were afterwards reproduced as positives on very thin glass plates, in order that they might be light in weight. The waltzing figures, taken in six positions, corresponding to the six steps to complete a turn, were duplicated as often as necessary to fill the eighteen picture-spaces of the instrument which was used in connection with the lantern to project the images upon the screen.

* The printed program of this event contains the following allusion to this feature of the entertainment: "THE PHASMATROPE. This is a recent scientific invention, designed to give to various objects and figures upon the screen the most * * life-like movements. The effects are similar to those produced in the familiar toy called the Zoëtrope, where men are seen walking, running and performing various feats in the most perfect imitation of real life. This instrument is destined to become a most invaluable auxiliary to the appliances for illustration, and we have the pleasure of having the first opportunity of presenting its merits to our audience."

The piece of mechanism, then named the "Phasmatrope," shown by the illustration, consisted in a skeleton wheel having nine radial divisions, into which could be inserted the picture-holders, each of which consisted of a card upon which was mounted two of the photo positives, in such relative position that, as the wheel was intermittently revolved, each picture would register exactly with the position just left by the preceding one. The intermittent movement of the wheel was controlled by a ratchet and pawl mechanism operated by a reciprocating bar moved up and down by the hand. It will be apparent that the figures could be moved in rapid succession or quite slowly, or the wheel could be stopped at any point to complete an evolution.

In the exhibitions at the Academy of Music, above alluded to, the movement of the figures was made to correspond to the time of the waltz played



by an orchestra, and when the acrobat performers were shown a more rapid motion was given, and a full stop made when a somersault was completed. A shutter was then a necessary part of the apparatus to cut off the light rays during the time the pictures were changing places. This was accomplished by a vibrating shutter placed back of the picture wheel, that was operated by the same draw-bar that moved the wheel, only the shutter movement was so timed that it moved first and covered the picture before the latter moved, and completed the movement after the next picture was in place. This movement reduced to a great extent the flickering, and gave very natural and life-like representation of the moving figures.

HENRY R. HEVL.

PHILADELPHIA, February 1, 1898.

NOTES AND COMMENTS.

FELT MATS FOR RAILS.

Engineers and railway men are much interested in the results of tests now being made abroad with mats of felt, which are designed for laying under the rails of street railway lines for purposes of protection and sound deadening. The new mat, which is a German invention, was first exhibited at Leipsic last summer, and attracted considerable attention. It is described as made of strong wool, which is thoroughly impregnated with oils, then superficially coated with glue, which has been rendered insoluble by the addition of sodium bichromate and formaldehyde, and then very highly compressed to form plates from ⅓ inch to several inches in thickness and of various sizes. They are especially recommended for crossings and bridges, but are desirable for use all along the track, and it is claimed that they tend to prolong the life of the rail by lessening the wear on it. The surface of the mat is said to be so hard that a rail may be placed upon such a piece of matting without cutting into it. In addition the claim is made that by placing the mats under the bed plates-bearings between the joists and other such places in the engine rooms, the noises therein will be reduced to a minimum. The material is known by the name of iron felt. The main question is as to how long the mat will retain its elasticity. Another recommendation for the preparation is that it prevents rotting.—*Iron Age.*

THE USE OF WATER METERS.

In Philadelphia, where some trouble is experienced in obtaining a proper supply of water, an attempt is being made to prevent the waste of water by the use of meters, to which some objection is being made. In commenting on this the *Ledger* makes the following observations: There should be no more opposition to water meters than there is to gas meters, and there would not be if the people were as well accustomed to the one as to the other. Their use is based on the same principle, and while there may be some difference in their application, since water is a necessity while gas is not, this is not enough to invalidate the principle. The use of water meters should be made compulsory and universal. It is true that water must be supplied to some persons who cannot pay for it, but it should be measured in every case, and the question of free delivery settled by itself. Measuring the water and paying for it are distinct questions, and need not be dealt with as inseparable. The use of meters is demanded as the only means to stop waste. At least half the water supplied to this city is wasted, and the waste not only costs as much money as the amount used, but it impairs the quality of the whole by withdrawing the water from the reservoirs before it has time to purify itself by subsidence. The introduction of meters would be the quickest way of affording relief in the water difficulty, and while it would not solve the problem it would help to preserve the health and comfort of the people while waiting for a pure-water system to be selected and installed.

CHEMICAL EFFECT OF CATHODE RAYS.

Some experiments on the chemical effect produced by the impact cathode rays, made by Professors Momson and Skinner, are thus reported by London *Nature:* "Aluminum is rapidly evaporated from the cathode by an electric discharge in a highly exhausted vacuum tube in which air has been replaced by mercury vapor. The metal is condensed over the walls of the tube in the form of a bright mirror. An iron cathode gives a similar mirror in a mercury vapor discharge tube. When the aluminum coating is dissolved off the wall of the bulb by hydrochloric acid a gelatinous membrane remains, which gives the reactions of silica. When potassium vapor is used the glass opposite the aluminum cathode is roughened. In parts sheltered by screens from the discharge the glass is not attacked. In potassium vapor the aluminum cathode is not evaporated to any marked degree. Opposite the cathode, both in the mercury vapor and potassium vapor bulbs, a dark annular stain of the shape of the cathode is formed. This stain resists the action of strong hot hydrochloric acid, nitric acid, aqua regia, and potash solution. The action of hydrochloric acid removed it, apparently by dissolving the glass. The t sts indicate carbon, but the quantity of the stain is too small to make certain. The stain is also formed on screens of mica, quartz and calcite. Monatomic gases appear to permit the evaporation of aluminum, as Professor Callendar has observed its evaporation in an argon vacuum tube."

EFFLORESCENCE ON BRICKS AND SANDSTONES.

Efflorescences from the materials of our buildings are not ornamental, nor do they render the stones more durable, says *The Trade Journals Review.* About their causes and prevention we are pretty much at sea. Contractors are occasionally required to use stones free of nitre; nitrates have, in reality, little to do with the matter, and it is generally sulphates which cause the trouble. Some years ago, the Association of German Architects invited memoirs on the question. The general conclusion seemed to be that prevention was very difficult, and that time would bring its cure. A dissertation by Hans Günther, communicated in abstract in *Dingler's Polytechnisches Journal*, is not quite so resigned. Günther has evidently made a very careful and painstaking study of this uninteresting subject. The trouble may come from the clay, the water employed during the various stages, the ashes and pyrites of the coal, and from the mortar. The pyrites of the coal may certainly cause mischief, especially because modern practice is in favor of continuous ring kilns, which work with plenty of oxygen; while in the old periodical kilns the atmosphere was frequently reducing, so that little sulphuric acid was formed from the SO_3. The presence of sulphuric acid, we learn incidentally, favors the production of colored bricks, for it decomposes the yellow iron-lime silicate. But the author attaches more importance to the pyrites in the clay, and to chemical interaction between brick and mortar. He has very fully gone into this inquiry. He found, *e. g.*, that certain bricks remained quite smooth when piled up, and became soon covered with efflorescences when used with a mortar which proved perfectly harmless to other bricks. Almost all clays contain pyrites, which, in the presence of magnesia, give rise to immediate efflorescences; in the presence of lime, only after decomposition

with the alkalies of the mortar. That the sulphates are the chief culprits he established beyond doubt. We may mention that the case is different in lavatories where ammonia is constantly liberated and slowly converted into nitrates. As a remedy, Günther suggests to admix baryta, as carbonate or chloride, which would bind the sulphuric acid. The sandstone blocks of the handsome new Town Hall at Hamburg suffer from this trouble.

A very intelligent discussion of this subject was published in this *Journal*, Vol. 106, p. 52, from the pen of Mr. Henry Pemberton. His paper related specially to the efflorescence on brick walls so generally seen in Philadelphia, and attributed the cause to the universal use, in Philadelphia, of dolomitic lime for the mortar used by our local masons. The action of the sulphurous gases from coal thrown out from innumerable chimneys, and carried down by rain water, in this author's opinion, explains the leaching out from the mortar of magnesium sulphate, which, after the drying out of the moisture, makes its appearance on the surface of the walls as a whitish coating. W.

REPORTED DISCOVERY OF STRONTIUM.

The discovery of a large bed of strontium sulphate at Put-in-Bay, reported from Toledo, has awakened a considerable amount of interest among the manufacturers of fireworks, as it is thought likely that it will result in a considerable reduction in the price of all fireworks in which strontium nitrate or strontium carbonate is used. One large manufacturer of fireworks in New York, who makes use of about 150 tons of strontium nitrate in a year and imports the whole of it from Europe, states that it costs his firm now about 7¼ cents a pound. If the strontium should be found in large quantities, it would have the effect of lowering the cost of certain classes of fireworks, that is, all those that use a red or crimson light. At present the supply comes chiefly from Germany, and the American manufacturer has to pay a high price for it. —*Scientific American*.

RECENT IMPROVEMENTS IN ARMOR PLATE.

Some mention has been made lately in foreign papers of a new process for making armor plate, which is said to produce a harder and better plate than the nickel-steel treated by the Harvey process, which has heretofore given the best results. The French Government has bought the right to use this process from the inventor, but the details have been carefully kept secret. It is also known that Krupp, the great German steel-maker, has a new process, which is either the same or a very similar one to the French. Enough is known of the process to say that it requires the use, in making the steel, of some of the rare metals, molybdenum, uranium and vanadium, which take place of nickel in the alloy resulting. We are informed by a correspondent, who has made many researches into the rare elements, that agents believed to be acting for the French Government are now in this country in search of deposits from which these metals can be obtained. French agents have also bought uranium ores in the West. The iron ores on which Mr. Edison has been at work with his concentrating plant at Edison, N. J., are understood to contain some molybdenite, and the other metals may be found also when it is known that a demand for them exists.—*Iron Age*.

BOOK NOTICES.

Annuarie pour l'An 1898, publié par le Bureau des Longitudes (pp. 613, 147). Paris: Gauthier-Villars et Fils. (Price, 1 fr. 50 c.)

The astronomical data in this volume of the *Annuaire* have been revised to date in accordance with the most recent discoveries. Several new charts exhibiting the magnetic elements in France have been coutributed by M. Monseaux; the chapter on tides has been rewritten; Bertholot's thermo-chemical tables have been brought up to date, and a number of other valuable and interesting communications are included in the volume. W.

Annuaire de l'Observatoire municipal de Montsouris pour l'Année 1898 (pp. 636). Paris: Gauthier-Villars et Fils.

This volume is devoted to an account of the observations made during the year 1896 by the several scientific bureaus under the direction of the Municipal Council of the city of Paris. They cover the branches of meteorology, chemistry, microscopy and hygiene, and may be studied with much advantage by all who are interested in subjects pertaining to public health and municipal administration. W.

Institute Organization: the plan and scope of the Brooklyn Institute, and its application to other cities. By Barr Ferree.

The above is a publication, in pamphlet form, of a paper presented by the author to the President and Council of the Brooklyn Institute. Mr. Barr Ferree gives a concise statement of the plan of organization and the methods employed by this Society, and offers some suggestions for the further extension of its work.

The remarkable growth of this notable organization, from a membership in 1888, of 82, to nearly or quite 5,000, at the present time, affords the most convincing evidence that the advantages it offers to the public by its educational methods are real. Notwithstanding its recent phenomenal growth in membership, the present rate of increase promises an even greater growth for the immediate future, the admirable flexibility of the organization permitting of an indefinite extension of its popular educational features. It is gratifying to know that the good work accomplished by the Institute has been recognized by the municipal authorities by the gift of a splendid museum building which will shortly be ready for occupancy. W.

Conclusions of the French Commission in Reference to Tests of Cements. The Influence of Sea Water on Hydraulic Mortars. (Translated from the French and from the German by O. M. Carter, Captain Corps of Engineers, U.S.A., and E. A. Gieseler, U. S. Assistant Engineer. Washington: Gov Print. 1897. 8vo. Pp. 77.

The first of these contributions contains the conclusions approved by a technical commission appointed by the Ministry of Public Works of France,

"to formulate uniform rules to be followed in testing materials of construction," etc. The contribution embraces the work of Section B, of the Commission, which was charged with the study of the questions relating to materials of construction other than metals, and is confined to the study of the methods of testing masonry materials, namely, cements, limes, pozzuolanas, sands and plasters.

The second contribution embraces several articles named below, viz.: The Influence of Sea Water on Cements, by Dr. Wm. Michaelis, a widely recognized authority on the subject of cements; a reply to Dr. Michaelis' article by the Board of Directors of the Union of German Portland Cement Manufacturers; and a paper on the same subject, by E. Coudlet.

The papers are all valuable contributions to our knowledge of the properties and behavior of these indispensable materials, and may be commended to the attention of engineers of public works. W.

The Elements of Electric Lighting, including electric generation, measurement, storage and distribution. By Philip Atkinson, A.M., Ph.D. Ninth edition. New York: D. Van Nostrand Co. 1897. 8vo. Pp. 289. Price $1.50.

Mr. Atkinson's "Elements of Electric Lighting" has been generally received as one of the best popular expositions of the subject adapted to the needs of the non-professional reader. The fact that a ninth edition has been found needful speaks for itself of the utility of the book.

In the present edition important changes have been introduced in the chapters relating to the construction of dynamos, to conform to the progress of the past few years. Other changes will be noted in the consideration of the subject of storage batteries; the vacuum-tube system of lighting receives a share of attention, and numerous other references to the most recent advances in the application of electricity to lighting will be found incorporated therein.

W.

Jahrbuch der Elektrochemie. Berichte über die Fortschritte des Jahres 1896. Dr. W. Nernst und Dr. W. Borchers. 3ter Jahrgang. Halle a. S. Verlag von Wm. Knapp. 1897. 8vo. Pp. 359, with numerous illustrations.

To manufacturers, electrical engineers and students the year-book of Nernst and Borchers affords the only comprehensive digest of current progress in the field of electro-chemistry, and it covers the ground very satisfactorily. This special branch of applied electricity is growing rapidly, and its importance in a few years more will be vastly greater than at present.

W.

The Elementary Principles of Machine Design, etc. By J. C. A. Meyer. New York: The Industrial Publication Company. 1897.

The office of this work is to serve the young mechanic as a guide in the practice of machine designing. It appears to be very well adapted to serve the author's purpose. W.

Sanitary Engineering. By Wm. Paul Gerhard, C.E. New York: The Author, 36 Union Square, East. 1898. 12mo. Pp. 132.

This work is a reprint in book form of a lecture delivered by the author before the Franklin Institute in 1895, and published in the *Journal.* Appended thereto is a paper entitled "The Work of the Sanitary Engineer in Time of Epidemics, in Time of War and in sudden Calamities in Civic Life," contributed originally by the author to the *Sanitarian* (1895). The material included in the book is a comprehensive and masterly exposition of the scope and limitations of sanitary engineering and of the duties and responsibilities of the sanitary engineer. W.

A Short Hand-book of Oil Analyses. By Augustus H. Gill, S.B., Ph.D. Philadelphia and London: J. B. Lippincott Co. 1898. 12mo. Pp. 139. Price, $1.50.

The above work is a concise manual, setting forth the most approved methods, physical and chemical, for the testing of oils, and, though primarily designed for the use of students of applied chemistry, will be found extremely serviceable to the practical chemist where more elaborate works on the subject are not accessible. W.

Practical Electricity: A Laboratory and Lecture Course, etc. By W. E. Ayrton, F.R.S., Assoc.M.Inst.C.E. Volume I, "Current, Pressure, Resistance, Energy, Power and Cells." With 247 illustrations London, Paris and Melbourne: Cassell & Co., Limited. 1896. Price, 9s.

This is an entirely rewritten, enlarged and modernized edition of a well-known and valuable text-book for electrical students. W.

Elements of the Differential and Integral Calculus, with explanations. By Wm. S. Hall, E.M., C.E., M.S., etc. New York: D. Van Nostrand Company. 1897. 8vo. Pp. 249. Price, $2.25.

This book is described by the author as designed for the use of colleges and technical schools as an introduction to the study of the calculus, and he has endeavored so to present the subject as to adapt it to the needs, not only of the student of mathematics, but also to those of the engineer who may wish to make application of the calculus in his work. W.

The Strength of Materials. A text-book for Manual Training Schools. By Mansfield Merriman. Fourth edition. New York: John Wiley & Sons. London: Chapman & Hall, Ltd. 12mo. Pp. 124. Price, $1.00.

In the treatment of the subject in this work, the author presupposes on the part of the student of such mathematical knowledge as is usually imparted in the high-school courses, embracing arithmetic, algebra, geometry and elementary mechanics. It should prove a useful adjunct to the course of study in the Manual Training Schools. W.

Franklin Institute.

[*Proceedings of the stated meeting held Wednesday, March 16, 1898.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, March 16, 1898.

MR. JOHN BIRKINBINE, President, in the chair.

Present (estimated) 350 members and visitors.

Additions to membership since last report, 15.

The Secretary reported the resignation of Mr. Wm. C. Henderson from the Committee on Science and the Arts. A special election was held to fill the vacancy, and resulted in the election of Prof. George F. Stradling.

Mr. Chas. E. Tripler, of New York, gave an account of his method and apparatus for liquefying the difficultly-condensible gases, and made a large number of experiments with liquefied air.

Of these, the more noteworthy were the behavior of the liquid under different conditions; the freezing of a great variety of substances; the characteristics of matter at the extremely low temperature of the liquid; the remarkable effects of the low temperature on the physical properties of metals, etc.

At the close of Mr. Tripler's demonstrations, which were extremely novel and of the highest interest, the meeting gave him a vote of thanks, and the subject of his system and apparatus was referred for investigation and report to the Committee on Science and the Arts.

Adjourned.

WM. H. WAHL, *Secretary.*

COMMITTEE ON SCIENCE AND THE ARTS.

Stated Meeting March 2, 1898. No quorum. Adjourned.

SECTIONS.

MINING AND METALLURGICAL SECTION.—*Stated Meeting* February 9, 1898.

Address of the retiring President, Mr. Benjamin Smith Lyman.

In laying down the office of President of the Section, I beg not only to thank you warmly for your kindly consideration during the past year, but to say a parting word or two on the scope and policy of the Section.

The Sections of the Franklin Institute have been established with the expectation of effectively promoting applied science of every kind by the inducements they offer men to undertake and make public and discuss original investigations of importance. The sagacious secretary of the Institute has long cherished and often expressed the hope, and apparently with excellent reason, that eventually the whole original scientific work of the Institute may be done through a considerable number of Sections, each cultivating its own field, and all harmoniously coöperating. Some progress has already been made towards establishing the Sections, and it seems probable that more of them may soon be started with advantage. Certainly, they are such useful

and effective means of carrying out the manifold purpose of the Institute that their formation and growth ought to be zealously furthered.

In order to encourage them, it seems desirable that their good work should not be hidden away out of sight, but should be made duly conspicuous to the whole Institute and to the world; and that it should be distinctly seen and acknowledged that they are the great constituents of the Institute, so far as the Institute undertakes to extend the bounds of applied science and the allied arts. If the Sections are best able to do the scientific work of the Institute, they also best know, each in its own branch, the needs of the Institute, and therefore deserve to have, as organizations, an important share in the management of the whole Institute. They should be not merely a sort of safety-valve for the harmless and unnoticed escape of superfluous zeal, but coöperating engines for more effectively and honorably utilizing the supply of power. It seems that the Institute will in time become essentially a combination or federation of Sections, as the United States is a federation of States; and that each Section should have its share in the management of the whole organization, either by equal representation in a Senate, a new coördinate governing body, or by a certain representation in the present Board of Managers. The Sections are as capable of wisely electing members of the Board as the general monthly meeting can be.

Each Section, moreover, has its own interests to promote within the Institute. For example, in our Section, we hope to establish an important museum of objects connected with the mineral industry, and we have consequently the strongest interest in obtaining from the Institute the proper space and means for arranging such a museum at the earliest possible moment. We ought therefore, as an organization, to have a voice in the disposal of any space or any funds that may be possibly employed for such a worthy purpose. At present we have, as a body, no representation whatever in the Board of Managers, and it seems only fit that, for the proper and effective prosecution of our reasonable demands in furtherance of the objects of the Section, we should have distinctly and of right some official representation in the management of the Institute.

Another very important means of increasing the usefulness of our Section is the encouragement of the social side of our meetings. Of course, the most vital point is to have valuable original papers and useful discussions of them; but the greater the certainty of an agreeable social chat after the serious work of the evening, the more sure is the gathering to be a large one, and consequently the better the inducement to prepare and read important papers. Besides, rather obviously, there are other very weighty benefits, both for personal advantage and for the promotion of science, to be derived from friendly social intercourse between the members of the Section. Every member or visitor who makes it a practice to stay awhile and chat after the adjournment helps towards that highly useful social feature of the meeting. It is hoped that before long we may emulate the Electrical Section, and give still further encouragement to the social side of the meetings by having some slight refreshments provided after the adjournment, to keep the hungry and thirsty in good sociable humor and prevent them from hurrying away too speedily. When the changes in the arrangement of the library have been completed, a few weeks hence, the main reading-room and museum will be a splendid

place for such social gatherings. Here, again, we shall perhaps need official representation in the management of the Institute, in order effectively to advance our wishes as a body.

Heartily congratulating the Section on its having obtained so excellent a chief for the present year, I have now great pleasure in calling upon Mr. Outerbridge to assume the presidency of the Section.

Stated Meeting, held Wednesday, March, 9, 1898. President, Mr. A. E. Outerbridge, Jr., in the chair.

Mr. James S. De Benneville was elected Secretary of the Section for the current year.

The President named the following standing committees for the year:

On Papers: Messrs. Benj. Smith Lyman, James Christie and Jas. S. De Benneville.

On Finance: Messrs. Joseph Richards, Henry G. Morris, and F. Lynwood Garrison.

The following new members were enrolled: Messrs. J. Selgreaves Cox, Robert B. Haines, Jr., and Harrison Souder.

Mr. Robert W. Lesley presented a paper, entitled "The Development of the American Portland Cement Indistry," which was discussed by several members and others. The thanks of the meeting were voted to the speaker, and the paper with discussion was referred for publication in the *Journal*.

Special Meeting, held Wednesday, March 23, 1898. President Outerbridge in the chair.

Prof. Alexis A. Julian, Columbia University, New York, presented a communication entitled "Building Stones: Elements of Strength in their Constitution and Structure." The paper was illustrated by the projection of thin sections, with the aid of the lantern microscope. (Referred for publication.)

CHEMICAL SECTION.—*Stated Meeting* held Tuesday, March 15, 1898. President, Dr. Lee K. Frankel, in the chair.

Mr. G. Morgan Eldredge read a paper entitled "A Method of Applying a Money Standard to the Nutritive Values of Feeding Stuffs, to which is Appended a Mode of Constructing a Balance Ration." The paper was discussed by Mr. Kebler and the author.

Mr. Paul R. Heyl read a brief communication "On a supposed Change of Weight with Change of Temperature," describing an apparatus which he had devised for an experiment bearing on the subject. The communication was discussed by Dr. Keller, Dr. Hall, Mr. Lee and the author. Referred for publication.

Mr. Aron Hamburger presented a communication on "Recent Developments in the Textile Industries," describing new methods for imparting a silky lustre to wool, various novel applications of formaldehyde, etc., etc. The subject was discussed by Dr. Keller and the author. Referred for publication.

ELECTRICAL SECTION.—*Special Meeting* Tuesday, March 1, 1898. President, W. E. Harrington, in the chair.

Professor Arthur Goodspeed, University of Pennsylvania, gave a lecture on "Recent Advances in Radiography," profusely illustrated with lantern views.

W.